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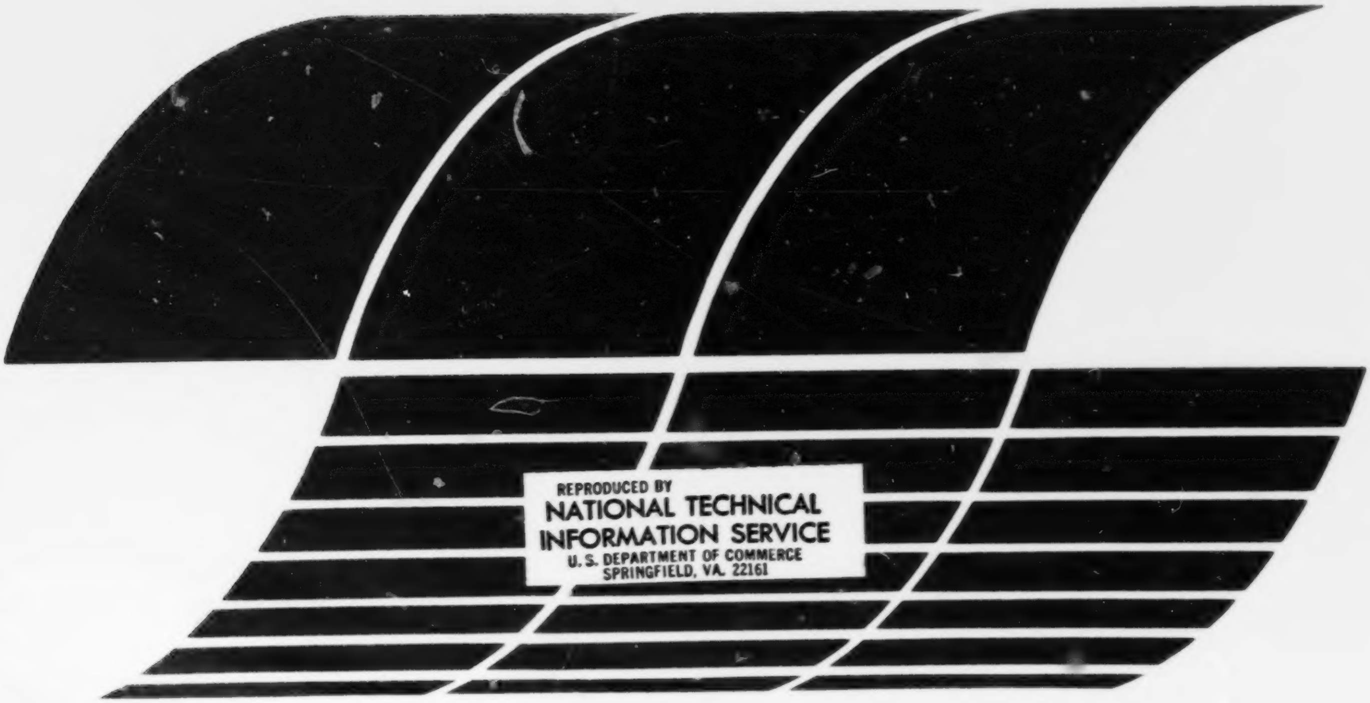
Reclamation of Alkaline Ash Piles and Protection of Their Environment Against Dusting

Interagency Energy/Environment R&D Program Report



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16. ABSTRACT

The objective of this study was to develop methods to reclaim and stabilize by vegetation fly ash and bottom ash from bituminous and lignite fired power plants. The ash had been transported from the power plant as a slurry and disposed of in ponds. Ashes from these power plants were strongly alkaline (pH from 8.5 to 12.8). Greenhouse experiments were conducted using white mustard (Synapis alba L.) as the test plant on ashes treated by various fertilizers, with various moisture levels and with application of amendments changing the composition or the properties of ash. Three years field experiments were performed to investigate the growth, health, yields and quality of mixtures of legumes and grasses growing on ashes with admixtures changing their composition or properties. Different fertilization levels were also studied. A 3-year field investigation of the growth and health of selected species of trees, bushes and cuttings was conducted. On the base of periodical pedological microbiological and phytosociological examination the process of the soil formation was observed.

Field experiments were carried out in a moderate climate, where significant air pollution, dusts, and gases were emitted from nearby power plants burning bituminous coal or lignite. Along with the results of the greenhouse and field investigations, recommendations for ash reclamation are presented.

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RECLAMATION OF ALKALINE ASH PILES AND PROTECTION OF THEIR ENVIRONMENT AGAINST DUSTING

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This report has been reviewed by the Environmental Protection Agency Region VIII Office and the Industrial Environmental Research Laboratory-Cincinnati and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names of commercial products constitute endorsement or recommendation for use. However, the report is believed to provide valuable information worthy of review.

FOREWORD

When energy resources are extracted, processed, converted and used, the related pollutional impacts on our environment and even on our health often require that new and increasingly more efficient pollution control methods be used. The U. S. Environmental Protection Agency through its Regional Offices and Office of Research and Development is striving to develop and demonstrate new and improved methodologies that will meet these needs both efficiently and economically.

The effort reported here was conducted as part of the Environmental Protection Agency's Scientific Activities Overseas Program and was a cooperative venture between Region VIII, Denver, and the Industrial Environmental Research Laboratory-Cincinnati. The research was conducted by Poltegor, the Main Research and Design Center for Open-pit Mining, Wroclaw, Poland.

In this report methods for the reclamation of ash disposal ponds have been investigated. The ashes from a bituminous coal and a lignite burning power plant were studied. Based upon these findings, recommendations for the reclamation of alkaline ash are made.

Results of this work will be of interest to persons concerned with the reclamation of power plant ash disposal systems. Furthermore, it should be of interest to those persons desiring a deeper understanding of the soils and vegetation aspects of reclamation of drastically disturbed lands.

For further information contact the Office of Energy Activities, Region VIII, or the Resource Extraction and Handling Division, IERL-Cincinnati.

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Cincinnati

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(Special Foreign Currency Program)

Scientific Activities Overseas, developed and implemented under the Special Foreign Currency Program, are funded from excess currencies accruing to the United States under various U.S. programs. All of the overseas activities are designed to assist in the implementation of the broad spectrum of EPA programs and to relate to the world - wide concern for environmental problems. These problems are not limited by national boundaries, nor is their impact altered by ideological and regional differences. The results of overseas activities contribute directly to the fund of environmental knowledge of the U.S., of the host countries and of the world community. Scientific activities carried out under the Program therefore offer unique opportunities for cooperation between the U.S. and the excess foreign currency countries. Further, the Program enables EPA to develop productive relationships between U.S. environmental scientists and their counterparts abroad, merging scientific capabilities and resources of various nations in concerted efforts toward U.S. objectives as well as their own.

Scientific Activities Overseas not only supplement and complement the domestic mission of EPA, but also serve to carry out the mandate of Section 102(2(E)) of the National Environmental Policy Act to "recognize the world-wide and long-range character of environmental problems, and where consistent with the foreign policy of the United States, lend appropriate support to initiatives, resolutions, and programs designed to maximize international cooperation in anticipating and preventing a decline in the quality of mankind´s world environment".

This study has been funded from Public Law 480. Excess foreign currency money is available to the United States in local currency in a number of countries, including Poland, as a result of a trade for U.S. commodities. Poland has been known for its extensive mining interests, environmental concern, and its trained and experienced engineers and scientists in this important energy area.

ABSTRACT

The objective of this study was to develop methods to reclaim and stabilize by vegetation fly ash and bottom ash from bituminous and lignite fired power plants. The ash had been transported from the power plant as a slurry and disposed of in ponds. Ashes from these power plants were strongly alkaline (pH from 8.5 to 12.8). Greenhouse experiments were conducted using white mustard (Synapis alba L.) as the test plant on ashes treated by various fertilizers, with various moisture levels and with application of amendments changing the composition or the properties of ash. Three years field experiments were performed to investigate the growth, health, yields and quality of mixtures of legumes and grasses growing on ashes with admixtures changing their composition or properties. Different fertilization levels were also studied. A 3-year field investigation of the growth and health of selected species of trees, bushes and cuttings was conducted. On the base of periodical pedological microbiological and phytosociological examination the process of the soil formation was observed.

Field experiments were carried out in a moderate climate, where significant air pollution, dusts and gases were emitted from nearby power plants burning bituminous coal or lignite.

Along with the results of the greenhouse and field investigations, recommendations for ash reclamation are presented.

This report was submitted in fulfillment of project number 05-534-1 between the United States Environmental Protection Agency and (the Central Research and Design Institute for Open-pit Mining), Poltegor, 51-616 Wroclaw, Rosenbergow 25, Poland.

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SECTION 1

SUMMARY

The object of the research was the in-situ examination of land reclamation procedures that appeared applicable to stabilize (to prevent dust) and revegetate coal ash produced from coal-fired electrical power plants. The ash consists of "bottom" ash collected from the bottom of the fire box and "fly" ash collected from electrostatic precipitators. The proportion of "bottom" ash was not exceeding 5 percent in the mass.

The investigations were carried out on alkaline ashes derived from the bituminous coal - fired Power Plant Halemba, and the lignite - fired Power Plant Konin. These ashes are commonly strongly alkaline and have a pH between 12.0 - 12.8.

Ashes from Halemba consist mainly of the minerals quartz (SiO_2) and mullite ($Al_6Si_2O_{13}$). Gypsum, magnetite, hematite and amorphous substances are found in smaller quantities. Due to content of about 47 percent SiO_2 and about 27 percent of Al_2O_3 the ashes are termed "aluminium siliceous" ashes. They are characterized by small amounts of CaO (about 4.5 %) and SO_3 (0.4 - 0.6 %). Ashes from Konin consist mainly of quartz, anhydrite ($CaSO_4$) and CaO. Hematite and magnetite occur in smaller quantities. Due to the high concentractions of SiO_2, CaO and SO_3 (36 - 90 % SiO_2, 28 - 34 % of CaO and 0.5 - 8.3 % of SO_3 the ashes from Konin are termed "calcium - sulphate" ashes.

All tested ashes are characterized with plant available potassium but lack of othercomponents nutritious to plants. Ashes from Konin are

more saline up to 2 % NaCl and contain more potentially toxic boron (up to 37.5 mg/kg of dry mass).

In the course of hydraulic transport of ashes to the pond disposal area, the pH decreases to between 8.5 and 9.5. The salinity and content of toxic boron also decreases. Despite this, such ashes are not fit for cultivation of vegetation. To facilitate vegetation of herbaceous plants, field and greenhouse experiments were performed using neutralized and fertilized ashes.

In greenhouse experiments, white mustard (Synapis alba) was planted in control mediums of: (a) mineral sandy - loamy soil; (b) sterile washed river sand, and (c) pure ash from disposal stacks with pH 8.5 - 9.5. Adopting as criterion the production of dry mass, the results of tests of neutralization and enrichment of ashes with nutritious substances are ranked (from highest to lowest crop production):

ashes from bituminous coal (Halemba)

1) mineral soil (control I);
2) ash + low moor peat (31.4 g/pot + NPK (nitrogen, potassium, phosphorus) Mg + m (microelements); (Pot volume = 7 kG of mineral soil);
3) ash covered with 1 cm layer of clay + NPK Mg + m;
4) ash + NPK Mg + m, by 80 % max. water capacity;
5) ash + low moor peat (31.4 g/pot) + NPK Mg + m;
6) ash strongly compacted + NPK Mg + m;
7) ash + 25 % of light soil + NPK Mg + m;
8) ash + mountain peat (31.4 g/pot) + NPK Mg + m;
9) ash + green manure of nitrogen-fixing plant (80.5 g/pot) + NPK Mg + m;
10) ash + mountain peat (31.4 g/pot) + NPK Mg + m;
11) ash + green cereal grass manure (80.5 g/pot) + NPK Mg + m;

12) ash + 2 (NPK Mg);

13) ash + NPK Mg;

14) ash + mountain peat + (31.4 g/pot) + 2 (NPK Mg) + 2 m;

15) ash + NPK Mg + m;

16) ash + sulphuric acid (125 ml/pot) + NPK Mg + m;

17) ash + gypsum (31.4 g/pot) + NPK Mg + m;

18) ash + mountain peat (31.4 g/pot) + sulphur (10 g/pot) +
+ NPK Mg + m;

19) ash + low moor peat (31.4 g/pot) + sulphur (10 g/pot) +
+ NPK Mg + m;

20) ash + low moor peat (31.4 g/pot + 2 (NPK Mg) + 2 m;

21) ash + low moor peat (31.4 g/pot);

22) ash + green cereal grass manure (322 g/pot) + NPK Mg + m;

23) ash + 25 % of river sand;

24) ash + mountain peat (31.4 g/pot);

25) ash + green nitrogen - fixing plant manure (322 g/pot) +
+ NPK Mg + m;

26) ash (control III);

27) river sand (control II);

ashes of lignite (Konin)

1) mineral soil (control I);

2) ash + low moor peat (31.4 g/pot) + NPK (nitrogen, phosphorus, potassium) Mg + m;

3) ash + NPK Mg + m (microelements);

4) ash + mountain peat (31.4 g/pot) + NPK Mg + m;

5) ash + 1 cm layer of clay + NPK Mg + m;

6) ash (control III);

7) ash + NPK Mg;

8) ash + 25 % of light soil + NPK Mg + m;

9) ash + mountain peat (31.4 g/pot) + NPK Mg + m;

10) ash + green cereal grass manure (80.5 g/pot) + NPK Mg + m;

11) ash + low moor peat (31.4 g/pot) + NPK Mg + m;

12) ash + sulphuric acid (125 ml/pot) + NPK Mg + m;

13) ash + 25 % of river sand;

14) ash + low moor peat (31.4 g/pot);

15) ash + mountain peat (31.4 g/pot);

16) ash + strongly compacted + NPK Mg + m;

17) ash + gypsum (31.4 g/pot) + NPK Mg + m;

18) ash + green nitrogen - fixing plant manure (80.5 g/pot) + + NPK Mg + m;

19) ash by 80 % maximal water capacity + NPK Mg + m;

20) ash + low moor peat (31.4 g/pot) + 2 (MPK Mg) + 2 m;

21) ash + low moor peat (31.4 g/pot) + sulphur (10 g/pot) + + NPK Mg + m;

22) river sand (control II);

23) ash + mountain peat (31.4 g/pot) + sulphur (10 g/pot) + NPK Mg + m;

24) ash + mountain peat (31.4 g/pot) + 2 (NPK Mg) + 2 m;

25) ash + green cereal grass manure (322 g/pot) + NPK Mg + m;

26) ash + 2 (NPK Mg);

27) ash + green nitrogen-fixing plant manure (322 g/pot) + NPK Mg + m;

The productivity of crops on all field ash plots were lower than that measured for crops grown in soil (control plot). In 3-years field experiments 5 types of mixes of grasses and nitrogen fixing plants were cultivated. Highest fodder value (in terms of conversion to protein) was acquired from grass mixture No. 2 as described below:

Grass mixture No. 2

- meadow fescue - Festuca pratensis Huds.	by weight	15 %
- orchard grass - Dactylis glomerata L.	"	5 %
- smooth bromegrass - Bromus inermis Leyss	"	15 %
- June grass - Poa pratensis L.	"	6.3 %
- creeping fescue - Festuca rubra L.	"	21.2 %
- white clover - Trifolium repens L.	"	3.8 %
- black medic - Medicago lupullina L.	"	8.7 %
- white melilot - Melilotus albus	"	3.8 %
- tall ryegrass - Arrhenatherum elatius P.B.	"	16.2 %
- bentgrass - Agrostis stolonifera L.	"	5 %
	Total:	100.0 %

The next highest fodder value was obtained from mixture No. 3:

Grass mixture No. 3

- alfalfa (lucerne) - Medicago media L.	by weight	85.7 %
- orchard grass - Dactylis glomerata L.	"	14.3 %
	Total:	100.0 %

Crops of both of these mixtures converted to air-dry mass amounted 0.87 to 14.28 t/ha in 1977. In Poland it is normally expected that crops from average fertile meadows and pastures should annually produce at least 3 t/ha. Taking as criterion the 3 t/ha of dry mass crop, one can conclude that positive results of neutralization, cultivation and fertilization were obtained in the following cases of field trials:

ashes from bituminous coal in Halemba:

grass mixture No. 1 Composition: alfalfa (Medicago sativa L.) - 83 % and white melilot (Melilotus albus Med.) - 17 %:

1) plots E-1, with addition of low moor peat + NPK - 10.99 t/ha
2) plots F-1, with addition of high moor peat + NPK - 7.71 t/ha
3) plots D-1, with addition of bentonite + NPK - 6.68 t/ha
4) plots G-1, with addition of farm manure + NPK - 5.76 t/ha
5) plots H-1, with addition of NPK - 5.73 t/ha
6) plots I-1, with double N2PK fertilization - 4.78 t/ha
7) plots 0-1, check without fertilization - 4.20 t/ha

grass mixture No. 2 Composition: mix of grasses:

1) plots A-2, with addition of 20 cm fertile soil + NPK - 10.83 t/ha
2) plots F-2, with addition of low moor peat + NPK - 9.61 t/ha
3) plots B-2, with addition of 10 cm fertile soil + NPK - 8.68 t/ha
4) plots C-2, with addition of 5 cm fertile soil + NPK - 8.29 t/ha
5) plots H-2, with addition of NPK - 6.82 t/ha
6) plots G-2, with addition of farm manure + NPK - 6.18 t/ha
7) plots F-2, with addition of high moor peat + NPK - 5.94 t/ha
8) plots I-1, with addition of double NPK dose - 5.76 t/ha
9) plots D-2, with addition of bentonite + NPK - 4.76 t/ha
10) plots 0-2, check - 4.73 t/ha

grass mixture No. 3 Composition: alfalfa (86 %) and orchard grass (14 %):

1) plots A-3, with addition of 20 cm of fertile soil + NPK - 7.11 t/ha
2) plots E-3, with addition of low moor peat + NPK - 6.93 t/ha
3) plots B-3, with addition of 10 cm fertile soil layer + + NPK - 6.83 t/ha
4) plots G-3, with addition of farm manure + NPK - 5.95 t/ha
5) plots F-3, with addition of high moor peat + NPK - 5.80 t/ha
6) plots C-3, with addition of 5 cm fertile soil + NPK - 5.69 t/ha
7) plots H-3, with addition of NPK - 5.64 t/ha
8) plots D-3, with addition of bentonite + NPK - 5.51 t/ha
9) plots I-3, with addition of double N2PK fertilization - 4.97 t/ha
10) plots 0-3, check - 3.45 t/ha

grass mixture No. 4 Composition: white melilot (Melilotus albus Med):

1) plots A-4, with addition of 20 cm of fertile soil + NPK - 9.60 t/ha
2) plots B-4, with addition of 10 cm of fertile soil + NPK - 8.75 t/ha
3) plots C-4, with addition of 5 cm of fertile soil + NPK - 6.02 t/ha

ashes from lignite in Konin

grass mixture No. 1 Composition: sainfoin (Onobrychis viciaefolia scop - 66.7 %, crown vetch (Coronilla varia L.) - 33.3 %:

1) plots H-1(K-1), with green manure + NPK - 4.96 t/ha
2) plots G-1, with farm manure + NPK - 4.69 t/ha
3) plots D-1, with tertiary sand + NPK - 3.94 t/ha
4) plots I-1, with double mineral fertilization, N2PK - 3.55 t/ha
5) plots E-1, with low moor peat + NPK - 3.53 t/ha
6) plots F-1, with high moor peat + NPK - 3.53 t/ha

grass mixture No. 2 Composition as provided earlier:

1) plots A-2, with 20 cm fertile soil layer + NPK - 13.78 t/ha
2) plots B-2, with 10 cm fertile soil layer + NPK - 12.68 t/ha
3) plots G-2, with farm manure + NPK - 12.40 t/ha
4) plots C-2, with 5 cm fertile soil layer + NPK - 10.66 t/ha
5) plots H-2, (K-2), with green manure + NPK - 9.93 t/ha
6) plots I-2, with double mineral fertilization, N2PK - 9.29 t/ha
7) plots F-2, with high moor peat + NPK - 9.13 t/ha
8) plots E-2, with low moor peat + NPK - 9.05 t/ha
9) plots D-2, with added tertiary sand + NPK - 7.62 t/ha

grass mixture No. 3 Composition provided earlier:

1) plots A-3 with added 20 cm fertile soil layer + NPK - 14.27 t/ha
2) plots B-3 with added 10 cm fertile soil layer + NPK - 12.14 t/ha
3) plots G-3 with added farm manure + NPK - 11.41 t/ha
4) plots C-3 with added 5 cm of fertile soil + NPK - 10.66 t/ha
5) plots E-3 with added low moor peat + NPK - 9.49 t/ha
6) plots H-3 with added green manure + NPK - 8.87 t/ha

7) plots F-3 with added high moor peat + NPK - 8.40 t/ha
8) plots D-3 with added tertiary sand + NPK - 8.22 t/ha
9) plots I-3 with added NPK - 7.10 t/ha
10) plots 0-3 check - 5.34 t/ha

grass mixture No. 4 Composition provided as above:

1) plots A-4 with added 20 cm of fertile soil + NPK - 8.56 t/ha
2) plots B-4 with added 10 cm of fertile soil + NPK - 7.87 t/ha
3) plots C-4 with added 5 cm of fertile soil + NPK - 5.54 t/ha

Prior to placing soil amendments and seeding vegetation on the ashes on the Konin disposal, the ashes were loosened up by blasting followed by deep plowing. Mineral nitrogen and phosphorus fertilization was added to all field plots before sowing and then spread after germination in a manner described in section 7 of this report.

Tree and shrub growth on ash disposal at both sites was investigated using the following species. (The species were ranked from best growing on disposals to poorest groving, applying here the criteria: Percent of losses and height increments):

Halemba:

Percent of losses		height increments	
1) locust tree	- 1 %	1) locust tree	- 2.12 m
2) poplar I	- 5.5 %	2) pea shrub	- 1.03 m
3) poplar II	- 11.1 %	3) poplar II	- 0.70 m
4) pea shrub	- 24.2 %	4) poplar I	- 0.62 m
5) basket willow	- 27.2 %	5) black alder	- 0.47 m
6) black alder	- 42.9 %	6) grey alder	- 0.47 m
7) grey alder	- 44.4 %	7) basket willow	- 0.33 m
8) larch	- 72.5 %	8) birch	- 0.29 m
9) birch tree	- 88.5 %	9) larch	- 0.28 m

Konin:

Percent of losses		Height increments	
1) poplar I	- 43.3 %	1) locust tree	- 0.63 m
2) grey alder	- 47.0 %	2) willow	- 0.49 m
3) poplar II	- 47.8 %	3) grey alder	- 0.43 m
4) willow	- 49.4 %	4) birch	- 0.36 m
5) pea shrub	- 52.0 %	5) black alder	- 0.35 m
6) larch	- 53.4 %	6) poplar II	- 0.31 m
7) sea buckthorn	- 55.3 %	7) poplar I	- 0.29 m
8) locust tree	- 58.3 %	8) sea buckthorn	- 0.28 m
9) black alder	- 58.4 %	9) pea shrub	- 0.13 m
10) birch	- 62.3 %	10) larch	- 0.11 m.

The above specified species are listed in order of decreasing growth from best growing ones on the disposals to the weakest growing, taking as criterion: the percentage of losses (failure of a tree or shrub) and the growth in height.

Trees and shrubs were planted in pits of dimensions ranging from 30x30x30 to 50x50x50 cm excavated in the ash. The pits were then filled with mixtures of ashes with amendments in the following five combinations (where the volumes are for a 1 m^3 of mixture volumetrically):

a) ash 0.75 m^3 + fertile soil 0.25 m^3;

b) ash 0.75 m^3 + Tertiary age sand 0.25 m^3 (only Konin), or ash 0.90 m^3 + bentonite 0.10 m^3 (only Halemba);

c) ash 1.00 m^3 + 8 kg of mountain peat;

d) pure ash and

e) fertile soil (only Konin).

It was found after 3-years' observation, that positive results were obtained on the disposal in Halemba in cases of locust tree and pea shrub. The method of pit dressing was shown to be unimportant.
On the disposal in Konin during the 2-years of research, no satisfactory growth was achieved (large number of losses, small growth).
The best results appear to be achieved when the trees and shrubs are planted in pits wholly filled with fertile soil.

Field Investigations of effectiveness of biological - chemical and physical protection of the surface against a repeated wind erosion involved seeding of grasses and legumes in varying mixtures, and covering of the ash surface with a water solution of latex in amounts of 0.10 mm (0.10 dm^3/m^3) and 0.20 mm (0.20 dm^3/m^3). On the basis of crop measurement in the second year of cultivation, a positive influence of latex on the yields of grasses and a negative action on the growth of alfalfa was found.

SECTION 2

CONCLUSIONS

1. Investigations were carried out on biological, chemical and physical stabilization and reclamation (agricultural and silvicultural) of disposal sites of alkaline ashes derived from burning bituminous coal (power plant Halemba) and lignite (power plant Konin). The results of investigations can be accepted as typical for ashes characterized with the following features:
   a) originate from bituminous coal or from lignite
   b) hydraulically transported to surface sedimentation basins
   c) alkaline
   d) salinity not exceeding 2 % (by weight), converted to NaCl
   e) soluble in water boron reserves up to 37.5 ppm.

2. Field experiments were performed in conditions of moderate climate (transient from oceanic to continental) with relatively low atmospheric precipitation in the first year at one site Konin 434 mm the first year (as against long term average of 517 mm), and with favourable precipitation in the remaining years. Negative results of the first year experiments in Konin are attributed to dry and cold conditions. In assessing results of the remaining years of the experiments in Konin and in Halemba, the positive influence of relatively large amounts of precipitation should be taken into account.

3. Field experiments in Konin and in Halemba were performed in close proximity to industrial activities including power plants which emit to the atmosphere relatively large amounts of particulates (dust fall 106 to 414 t/km^2/year) and potentially toxic gases (maximum 20-minute concentrations of SO_2 and F measured were

2.9 and 0.145 mg/m^3 respectively). This pollution has an adverse effect on the vegetation, particularly in the case of growth and survival of trees and shrubs.

4. Chemical and mineralogical composition and differentiated physico-chemical properties determine the classification due to suitability for the soil formation. And so ashes from Halemba containing mullites and typified with presence of 21.8 to 27.5 percent Al_2O_3 must be included to aluminous. The ashes from Konin on the other hand characterized by the 3.25 to 34.1 percent CaO and 0.48 to 8.3 percent SO_3 content - occurring mainly in the form of calcites and anhydrites - are included to calcium - sulphatic ashes.

5. Ashes from lignite and from bituminous coal are characterized by their strongly alkaline reaction (pH 11.5 to 12.8) and for this reason are not suitable without modification of amendment for vegetation.

6. The pH of the ash was reduced to between 8.0 and 9.5 by the process of hydraulic sluicing of the ash to sedimentation basins. The calcium - sulphatic ashes characteristic of the lignite at Konin were noted to change their properties in terms of CaO and MgO changing to carbonates and sulphates. In the aluminium rich ashes at Halemba characteristics of the chemical transformations are not so intensive.

7. Fly ash retained by electrostatic precipitators are highly saline (to 2.0 % $NaCl$). Reduction in the salinity occurs when the fly ash is hydraulically sluiced to the sedimentation basins, and by rain water, to such an extent that on experimental plots it was not exceeding 0.82 percent in Konin, and 0.16 percent in Halemba.

8. The ashes show sufficient reserves of available (to plants) potassium. But there is shortage of available nitrogen and phosphorus. Significant magnesium occurs in bituminous ashes from Halemba, as does calcium in lignite ashes from Konin. Manganese occurs in large quantity but is not assimilable to plants due to alkaline reaction of ashes.

9. Of the potentially toxic substances soluble in water, boron occurs in excess (up to 37.5 ppm) in the ash. Concentrations of molybdenum, cobalt, selenium and cadmium were found to be normal. Boron concentrations are reduced by leaching of infiltrated precipitation and as a result of assimilation by legumes.

10. Ash radioactivity (in particular the total alpha and gamma radiation) is higher in comparison with normal soils. Thus some increase in radioactivity of harvested crops is expected. It appears, however, that accumulated quantities are not harmful to humans or animals.

11. Ashes are characterized by particle size distribution of silts. The ashes are permeable - but their water retention characteristics are poor.

12. Protection of ash disposal from wind erosion can be achieved by consolidation with chemical and biological methods. Successful results were achieved by first spreading a water solution of latex (10: 1) and then sowing with mixtures of grasses and legumes accompanied by organic or mineral fertilization. Covering with latex can adversely affect the germination and development of legumes, but does not influence the development of grasses.

13. Greenhouse experiments have shown that neutralization of alkaline ashes by acidification with means used in agriculture (flowers of sluphur, sulphuric acid, gypsum) do not give the expected results. Additions of such materials of acid reaction as low and high moor peats, green manures and fertile soil did tend to lower the pH somewhat, probably because they loosened the soil material facilitating the leaching of alkaline materials.

14. Mineral fertilization hinders germination of the plants, retarding their development. High doses of fertilizers can prevent germination. It was found most advantageous to apply nitrogenous and phosphatic fertilizers in small doses long before the sowing of seeds, and then to apply a profuse fertilization to the surface

after germination and after each mowing. Response to such fertilization is great. Fertilization with micro - components in large doses was found to hinder growth of plants in greenhouse experiments.

15. The most positive effects exerted on growth of plants and on the formation of soil were caused by additions (to the ashes) of fertile soil, bentonite peats and farm manure. Positive influence depends on the amount of substance added. A directly proportional relationship was ascertained between crop productivity and thickness of soil layer, and between productivity and soil fertility.

16. The addition of substances such as fertile soil, bentonites, peats, farm manure, green manures increase nutrients, reduce alkalinity, increase sorptive and water capacity, reduce radioactivity through dilution, increase biological activity, and improve biochemical processes in the ashes.

17. Those ashes to which organic substances (farm and green mass manures) were added showed increased productivity in the second year of growth.

18. The best vegetative species in terms of productivity were found to be grasses and alfalfa (Medicago sativo). Orchard grass (Dactylis glomerata) was found to grow aggressively. White melilot (Melilotus albus) sown alone did not produce the expected effects, nor did the crown vetch (coronilla varia) or sainfoin (Onobrychis viciaefolia).

19. Mixtures of legumes with grasses make a good forecrop for the cultivation of cereal grains and industrial plants such as flax, hemp, rape, barley and sunflowers. Cultivation of root (potatoes, beets, onions) crops is not advised due to numerous treatments contributing to harmful dusting of ashes.

20. In tests of forest reclamation consisting of planting trees and bushes in pits dressed with fertile soil, with peat, bentonite and

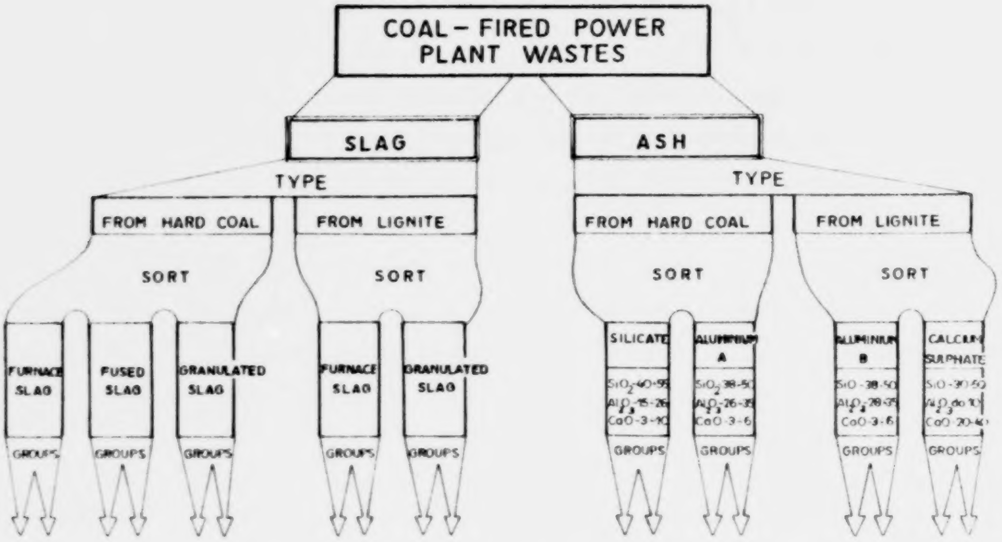
COAL - FIRED POWER PLANT WASTES
SLAG
ASH
TYPE
TYPE
FROM HARD COAL
FROM LIGNITE
FROM HARD COAL
FROM LIGNITE
SORT
SORT
SORT
SORT
FURNACE SLAG
FUSED SLAG
GRANULATED SLAG
FURNACE SLAG
GRANULATED SLAG
SILICATE
ALUMINIUM A
ALUMINIUM B
CALCIUM SULPHATE
SiO2-40-55
Al2O3-15-26
CaO-3-10
SiO2-38-50
Al2O3-26-35
CaO-3-6
SiO-38-50
Al2O3-28-35
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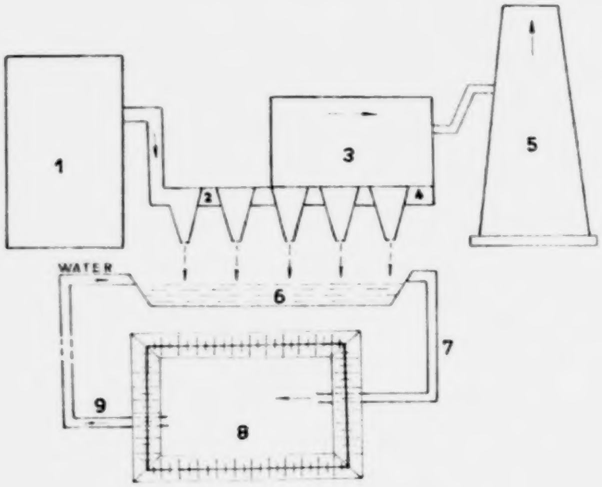
Fig. no. 1. Classification of power engineering waste materials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2
3
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5
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8
9
WATER

Fig. no. 2. Flow diagram of ash disposal in power plant: 1-boiler, 2-chutes before the electrofilters, 3-electric precipitators, 4-electric precipitators chutes, 5-stack, 6-ash tank and water quenching, 7-hydraulic transport of pulp, 8-sedimentation basini, 9-draining of the sedimentation basin.

mineral fertilizers - encouraging results were achieved in cultivation of locust tree (Robinia pseudoacacia), pea shrub (Caragana arborescens) and sea buckthorn (Hippophae rhamnoides) on aluminium - rich ashes from Halemba. Locust and sea buckthorn survived moderately well in calcium - sulphate - rich ashes at Konin. Unsatisfactory results were obtained with grey alder (Alnus incana), black alder (Alnus glutinosa), willow (Salix sp.), poplar (Populus sp.), and white birch (Betula verrucosa). At both sites though the survival and growth rates of most trees and bushes planted at Konin were not satisfactory, the best results were achieved where the pits in the ash were filled with soil and were fertilized with NPK.

21. Failures of trees and bushes is attributed to the relatively high salinity of ashes at the greater depths necessary to support the root system as well as to the air pollution.

22. The short period available for research did not allow for acquisition of sufficient data to generalize as to changes in ash-soil characteristics at depths equivalent to the root zones of trees.

23. The concentrations of ^{226}Ra in water in contact with ashes (table 27) are much higher (5.96 - 88.99 pCi/dm^3) than average ones observed in uncontaminated surface waters (0.2 - 1.0 pCi/dm^3), and would be hazardous for drinking water supplies. For this reason prolonged contact of ashes with surface and underground waters should be considered as undesirable.

SECTION 3

RECOMMENDATIONS

On the basis of performed investigations the following recommendations are offered:

1. Owing to leaching of potentially toxic substances (sodium and boron) and reduction in alkalinity caused by hydraulic sluicing of ash to sedimentation basins, it is recommended that an open system of slucing be continued as advantageous for purposes of reclamation using vegetation. However, the fate of leached elements and compounds must be determined. (It is presumed that these elements are redeposited in deeper layers of the ash - however, this has not been quantitatively demonstrated).

2. In order to intensity the leaching of sodium and boron from the ash, the sluiced ash should be loosened to a depth of 30 to 50 cm, thus facilitating additional leaching by precipitation.

3. Ash should be covered by latex, fertilized, and planted with legumes and grasses to prevent wind erosion and to use the surface productively. Positive results were obtained applying the following methods:

   a) Crumbling of the near-surface layer of disposal to at least 20 cm depth - employing rototillers - and in the case of calcium - sulphatic ashes by means of explosives or rippers and rototillers was effected.

   b) Sowing of mineral fertilizers in preseeding and outside the roots according to pt. 5.

   c) Seeding of grasses and perennial legumes as pt. 6.

d) Harrowing or raking of surface, then rolling with a light roller.

e) Surface covering with the latex water solution, Latex - LBSK - 5545 (production of Oświęcim Chemical Works in Poland) in proportion 1:10 (the seeding is possible jointly with the solution of Latex) - in dose rate 833 dcm^3/ha of Latex, which makes a film layer 0.08 mm thick.

f) Better certainty of biological consolidation can be achieved using neutralization of ashes as per pt. 4.

4. The alkaline ashes are best prepared for planting through one of the following soil amendment procedures:

   a) covering with fertile soil the effectiveness of this treatment is directly proportional to the thickness of the soil layer,

   b) mixing in farm manure applied at a rate of 20 t/ha (dry mass),

   c) mixing with green manure applied at a rate of 40 t/ha order,

   d) low or high moor peat in doses of 10 - 100 t/ha rank.

5. Fertilization prior to seeding must be limited to small amounts of nitrogen and phosphorus, in order not to hinder germination. Further fertilization is necessary after germination and should be limited to nitrogen and phosphorus at rates of 50 to 100 kg each per 1 ha identical fertilization after each cutting (harvesting) in the Spring is recommended.
   Positive results were achieved using the following mineral fertilization:

   a) in pre - seeding prior to rototiller mixing to 20 cm depth:
      - 140 kg of P_2O_5 in the form of 46 percent treble superphosphate (300 kg/ha of commercial fertilizer)
      - 35 kg N in form of 34 percent ammonium nitrate (100 kg/ha of commercial fertilizer) - only on aluminous ashes at Halemba;

   b) in pre - seeding with harrowing:

- 70 kg of P_2O_5 in the shape of 46 percent treble superphosphate (150 kg/ha of commercial fertilizer)
- 50 kg N in a shape of 34 percent ammonium nitrate (150 kg/ha of commercial fertilizer)
- 30 kg K_2O in shape of 60 percent of potash salt, (50 kg/ha of commercial fertilizer);

c) outside the roots

- 35 kg N in shape of 34 percent ammonium nitrate (100 kg/ha of commercial fertilizer);

d) early in the Spring and after first harvest gathering (with harrowing):

- 60 kg P_2O_5 in shape of 18 or 46 percent of superphosphate (respectively 400 or 130 kg/ha of commercial fertilizer);
- 100 kg N in form of 46 percent urea 220 kg/ha of commercial fertilizer.

6. Grasses and perennial legumes are recommended as the initial vegetation for treated ash. Orchard grass (Dactylis glomerata), the annual meadowgrass (Poa pratensis), the creeping fescue (Festuca rubra), the bentgrass (Agrostis stolonifera), and among legumes the black medic (Medicago lupullina), and lucerne species (Medicago media) are recommended. On stands rich in calcium, sainfoin (Onobrychis viciaefolia) can be used.
In carried out field experiments positive results gave application of 2 mixtures of grasses with legumes:

a) mixture with grasses predominant:

- meadow fescue (Festuca pratensis)	12 kg
- orchard grass (Dactilis glomerata)	4 kg
- smooth bromegrass (Bromus inermis)	12 kg
- annual meadowgrass (Poa pratensis)	5 kg
- creeping fescue (Festuca rubra)	17 kg
- white clover (Trifolium repens)	3 kg

- black medic (Medicago lupulina)		7 kg
- white melilot (Melilotus albus)		5 kg
- tall oat-grass (Arrhenatherum elatius)		13 kg
- redtop (Agrostis stolonifera)		4 kg
	total	82 kg

b) mixture with legumes predominant:

- alfalfa (Medicago sativa)		36 kg
- orchard grass (Dactilis glomerata)		6 kg
	total	42 kg

Better results were achieved using the specified above mixture in double dose rate i.e. 160 and 84 kg/ha. In the case of unsatisfactory germination recommended is a supplementary undersowing.

7. Stabilization and reclamation through introduction of trees for lumber is not recommended, due to the difficult soil conditions. However, when necessary in limited areas used to protect broad expanses or slopes from erosion, such species as locust tree (Robinia pseudoacacia), pea shrub (Caragana arborescens), sea buckthorn, (Hippophae rhamnoides) can be used on clayey - siliceous ashes, and sea buckthorn can be used on calcium - sulphatic ashes.

8. Investigations should be continued into more effective methods of desalinization and pH reduction of the ash, into the degree of ionizingradiation, harm and cumulation of radioactive substances in crops, and also on increasing the assortment of plants to be used in reclamation. Necessary also are long term measurements of the grasses and legumes since the 2-3 years measurements fall somewhat short of vegetative (and possibly climatic) cycles.

SECTION 4

THE STATE OF THE RESEARCH UP TO THE PRESENT

INTRODUCTION

It is estimated that future production of coal ash waste in Poland will increase as follows:

- in 1980 - 17.5 million tons
- in 1985 - 24.5 " "
- in 1990 - 30.0 " -

Assuming that the ash is disposed of in deposits averaging 20 m high, the land requirements necessary for storing this waste material in the period 1975 - 1990, amount to over 210 km^2 of land area, or about 0.07 % of the country's territory. This estimate was made assuming that no dramatic utilization of this waste product will occur.

Obviously it is important to store such ash in a manner compatible with regulations protecting the natural environment and allowing economic utilization of the land surfaces covered by the ash.

Dependent on their origin the wastes from power plants and from thermal-electric power plants operated on a coal fuel can be divided into two main groups (fig. 1):

a) ash from bituminous coal burning
b) ash from lignite.

Both the first and the second type of waste material can be further subdivided into bottom ash and into fly ashes. The bottom ash is produced in a furnace chamber of a boiler during the combustion process. Fly ashes are the sintered particles of a waste rock, collected in electrostatic precipitators from combustion gases. These two groups of ashes are usually mixed together for disposal.

In Poland the costs of ash disposal are currently lowest when hydraulic transportation is used to slurry the ashes to sedimentation basins. The ash is deposited in incremental lifts of 2 to 5 m. Dried ash is used to contain the slurry.

The water - ash pulp is transported on the disposal sites in pipelines (fig. 3). Water is drained from the settling basin and recirculated for reuse in the hydraulic sluicing operation.

The settling characteristics of the sedimentation basins are reflected in the distribution of ash by particle size and weight.

The following patterns are evident in the distribution of ash: 22

a) weight density of ashes decreases with increasing distance from the pipeline outlet;

b) organic content of ashes increases with increasing distance from the outlet;

c) mean particle size decreases with increasing distance from the outlet;

d) the coarsest fractions settle first, in view of this the disposal storage in its vertical cross-section has a streaky - bandy structure with alternately placed coarsely grained and finely grained layers (fig. 4).

In other situations dry ash disposal is practiced in Czechoslovakia, German Democratic Republic and Poland. In these cases the ash is quenched and hauled by rail or conveyor to the disposal area. There is no particle size or density sorting of wastes under dry disposal conditions. Stabilization and reclamation of dry disposal sites were not included in the scope of this research effort.

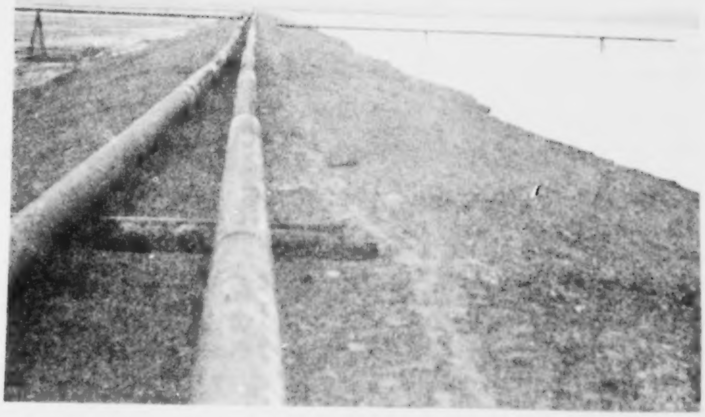

Fig. no. 3. Hydraulic disposal of ashes in sedimentation basins.

Fig. no. 4. Halemba – the site of field experiments.

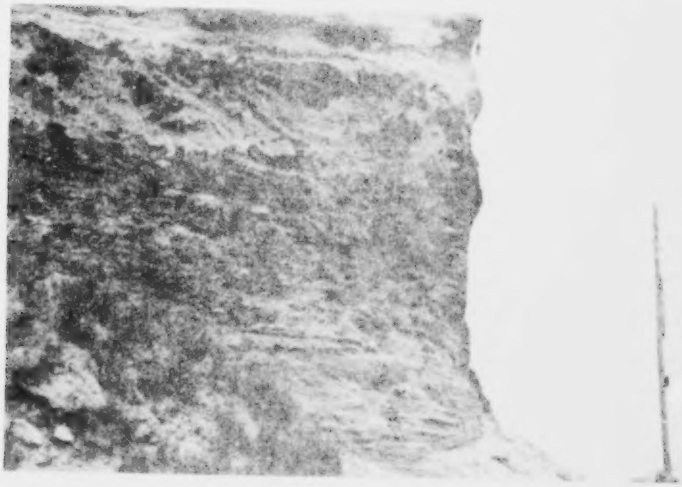

Fig. no. 5. Halemba – vertical section of ash disposal stack.

In view of the shortage of land area for ash disposal in the neighbourhood of power plants, hydraulic disposal of wastes in sedimentation basins is more frequently used for interim disposal. Then, after draining, the ash is transported to more distant, centralized sites. In such cases a belt conveyor, or rail-road transportation and dry disposal is employed [30].

On the basis of present research one can say that ashes from the polish bituminous coal are comprised principally of silica (about 40 %), aluminium oxides (about 20 %), iron oxides (several percent), and oxides of magnesium, calcium, sodium, potassium. The amount of unburned coal in the ash also amounts to several percent. Mineralogically ashes consist mainly of quartz, amorphous carbon, and mullite ($Al_6Si_2O_{13}$). Chemical composition of fly ash produced from American coal appears similar [1].

Lignite deposits in the Konin area are calcium - sulphate type, fundamentally different than the alumino silicate type produced from bituminous coal.

Ashes from the lignites of the Konin area according to present studies - contain from 3.0 to 7.1 percent of Al_2O_3. Content of CaO in ashes from Konin is from 5.0 to 46 percent. In a mineralogical respect Konin ashes consist of grains of quartz, calcite and of minerals of a montmorillo-illite group, ash from other lignites located in the Turoszów region are richer in Al_2O_3 (37 %) and contain less CaO (1.4 % average, 7 % maximum). Ashes from the Czech lignites have a composition similar to the Turów ashes [16, 17, 18].

Ashes from bituminous coal are characterized by a strongly alkaline reaction (pH 9.0 - 12.6). This may be reduced as the ashes "age" to a pH of 8.5. However, only small amounts of vegetative nutrients (particularly N and P_2O_5) are left in the ash. Porosity of the material is considerable, but the capacity for storage of water available to the plants is small. Ashes of the Konin's lignite contain large quantities of Ca and S. In the course of combustion calcium oxide is

Fig. no. 6. Konin - the site of field experiments.

Fig. no. 7. Konin - blasting of solidified ashes.

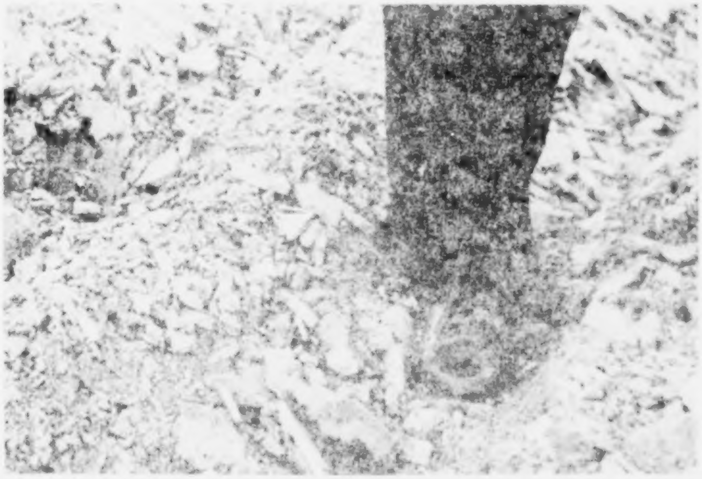

Fig. no. 8. Konin - ashes after blasting and tilling.

formed from the calcium compounds, and it combines with water during its hydraulic transportation producing hydroxides of calcium. Their combinations with sulphur, coal, sodium produce $CaSO_4$, or $CaHSO_4$, $CaCO_3$ or Na_2SO_4. Thus a gypsum-carbonate rock is formed by the ash.

Suitability of ashes for a biological consolidation thus varies and will depend upon the type of burned coal, on the technology of combustion, on the manner of ash disposal, and on the age of disposal stacks.

DUST SUPPRESSION - SUMMARY OF PREVIOUS RESEARCH

The surface layer of the ash deposits weathers and is subjected to water and wind erosion. Fugitive dust problems do result from the wind erosion. At present the water erosion is localized by the seams used initially to contain the ash - water slurry.

In order to choose the most effective means of preventing formation of fugitive dust, alternative treatments of ash piles were examined; these were:

a) the coverage of surface of ash with a non-erosive layer of mineral soil;

b) coverage of surface with film forming substances;

c) biological or biological - chemical consolidation of the surfaces.

The first method is the most effective but little used due to difficulties of obtaining adequate non-erosive soils. As a rule such treatment can be considered where economic utilization of the area for the purposes of agriculture or forestry is intended.

An initially effective, but not very durable treatment is the method of covering ash with film-producing substances or consolidating the surface. More than 30 substances were tested [32, 34], that could create either the semipermeable conditions or conditions consolidating superficial layers of ash. Every attempt was made to utilize substances which are wastes from other branches of industry. The best results were obtained using clutan product (lye of sulphitation). One-percent in solution applied at a rate of 0.5 l/m^2 wholly protects the ashes against dusting. Positive results were also obtained using the flushing water used to regenerate phenolic resins; this water was applied at a rate of 1.5 l/m^2.

Good results were also achieved using a 3 percent osacryl and a 30 % osacryl solution modified with latex (S136) applied at a rate of 1-2.5 l/m^2. Positive results were shown with application of detergent solutions, such as a 3 percent water solution of the fluid "Ludwik" and a 1 percent solution of the sulphapol. Use of these substances is limited since they are easily eroded from the surface and they offer only small resistance to mechanical disturbances of the soil such as are caused by walking or running a vehivle over the surface of the ash [32, 34].

During previous research near the power plant Jaworzno II, about 15 ha of the ash disposal surface was covered with a 20 percent asphalt cationic emulsion. This treatment both prevented wind erosion, and permitted infiltration of water. On plots covered with this emulsion the plants germinated and were growing very well and this is attributed to the protection of seeds against wind erosion and a greater retention of humidity in upper layers of the ash subsoil [6].

In field tests conducted by other researchers in the period 1971-72 [6, 12, 22, 34], other substances protecting against dusting were used, such as curasol and molasses as well as osacryl. Vegetation test experiments did not indicate any negative effects on the plant growth. The materials are applied to the surface by spraying. Selection of spraying equipment depends on the size and the configuration of a treatment site and on the dust suppressing substance employed.

In 1969 tests were carried out using soil binding materials such as cement and gypsum [22]. Also tested were oil-water emulsions using recycled machine oil. Analysis of results gathered from wind tunnel tests indicates that the effectiveness of an oil - water emulsion increases with the decrease in content of water in same emulsion. A drawback of the oil - water emulsions is the adverse effect on vegetation. Moreover, the presence of oil limits further use of ash for production of building materials [22].

The Central Office of Research and Water Melioration Projects has investigated the approach of sprinkling ash disposal areas with water in order to prevent wind erosion and to improve conditions for the vegetation life [6,9] with good results. In the course of these studies the maximum safe gradient of slopes of a dry ash disposal was determined to be 26° (about 1:2). Also successfully tested were transplanted grass mats placed directly on an ash subsoil [6, 11]. During the first few days these carpets required irrigation. After 2 weeks the grass mats were completely tied to the subsoil.

In the quoted publications no more detailed descriptions of substances used or their manufacture were provided.

Advanced tests of biological protection of ash against wind erosion have been conducted in Poland near Oświęcim; this ash is produced from low grade bituminous coal [8, 23]. The mesh analysis of these ashes indicated the following distribution:

- grains under 1 mm size - 61 to 84 %
- grains from 1 - 3.5 mm - 7 to 29 %
- grains above 3.5 mm size - 2.5 to 7 %.

The effuents from the disposal were characterized with pH 11 the ash disposal areas supported a natural succession of the following plants:

- Funaria hygrometrica Hedw. (moss)
- Carex hirta L. (hairy sedge)
- Poa annua L. (annual meadow grass)
- Poa trivalis L. (rough stalked meadow grass)
- Atriplex hastatum L. (spear leaved orache)

- Capsella bursa - pastoris L. Med. (shepherd's purse)
- Chameaenerion angustifolium L. (firewood)
- Chenopodium album, glaucum, polispermum, rubrum (white, glaucous, many seeded, red goosefoot)
- Polygonum aviculare L., minus Huds, persicaria L. (knotweed, minor knotweed and persicary)
- Potentilla anserina L. (silverweed cinquefoil)
- Senecio vulgaris L. (common groundsel)
- Salix sp. (willow)
- Sambucus nigra L., S. racemosa L., (golden elder, red berried elder)
- Tusilago farfara L. (common coltsfoot),
- Utrica dioica L., (stinging nettle).

It appeared that Funaris hygrometrica (moss) appeared first. Trees were planted on a bank of peat as part of the experiments. Results of tests indicated the following: poor growing: Ulmus scabra Mill (Scotch elm), Betula pubescens Ehrh. (common birch), Robinia pseudoacacia L., (locust tree). Fair growing: Populus balsamifera L. (balsam poplar), Populus italica Much. (black poplar), Alnus incana L. Much (grey alder), Alnus glutinosa L. Gaerth (black alder), and Salix acutifolia Willd (sharpleaf willow). Best suited: Tamarix caspica i Tamarix odessana (the tamarisks). However, in subsequent years it was decided to cover disposal with fertile soil, as the previous vegetative growth was considered insufficient [8, 23].

Żak [34] performed tests sowing grasses over the tops and slopes of ash disposal sites and covering these surfaces with asphalt emulsion. These tests had shown no toxic action of emulsion, and improved protection of seeds.

Tarczewski [25,26] states, that the ashes from the Ural power plants he investigated were rich in microelements, but did not possess adequate nutrient substances in assimilable form. In order to enrich these ashes with the nitrogen, the ash was covered with a layer of fertile soil (2 cm), or peat (4 cm), NPK fertilizer was added along with municipal sewage waters. Subsequent observations have shown excellent response to these methods, particularly to the use of municipal sewage. The planting of trees and shrubs in pits filled with 20-30 cm layers of soil was successful, especially with willows, poplars, apple trees and birches. On plots treated with sewage waters mesophytes and hydrophytes appeared first and were followed in the second year by self - seeded willows, aspens and birches. The tests were conducted on ashes with a pH of 6-7.

Pikałowa [21] carried out tests using vegetation on ash having an acid pH (pH 5.2). The tests were made in the following treatment combinations: (a) ash covered with a 3-4 cm layer of peat; (b) ash + + NPK; (c) ash + NPK; (d) ash + amide of poly-acrylate; (e) ash - no treatment; (f) soil - no treatment. Seeds were sown at a rate two times greater than used for normal field sowing. Germination of seed planted in pure ash was disappoining. Growth of plants on ash treated with peat and those fully fertilized was good. From 24 species of plants, the hardiest are the grasses. Such grasses include Gromus inermis (smooth bromegrass); Roegneric fibrosa (slender wheat grass), Festucca rubra (creeping fescue), Festucca pratensis (meadow fescue), Agropyron cristatum (crested wheat grass), Agropyron tenerum (wheat grass), Dactilis glomerata (orchard grass), Beckmania eruciformis Host. (slough-grass), and papilionaceae: Medicago media (lucerne species), Melilotus alba (white melilot).

Ština investigated [24] the development of micro-flora on slightly alkaline (pH 7.6 - 7.9) waste ash and concluded that the ashes contain iron, aluminium and manganese in toxic quantities. Vegetation appearing first on such ashes are cyanoses and in this the Nostoc forms combining the nitrogen. She found that fertilization stimulated microflora development.

Vaniček states that in Czechoslovakia a site disposal of ash and slags was planted in 1954 - 1957 with 43 species of trees and bushes (2576 specimens) and 84 varieties of grasses and herbaceous plants [28].

After 4-7 years, 16 species of trees and shrubs were established (1292 pieces) as were 26 varieties of grasses and herbaceous plants. The best development of plants took place where peat and mineral fertilizers were added to the ash [28].

The following varieties of trees were recommended as suitable for stabilization:

- Ailanthus glandulosa (tree of heaven)
- Popolus canadensis (Canadian poplar), P. nigra (black poplar), P. Simonii (Simons poplar), P. alba (white poplar), P. Charkoviensis (Charkov poplar)
- Tamarix gallica (tamarisk)
- Elaeagnus angustifolia (Russian olive)
- Colutea arborescens (English name wanting)
- Evonymus europaea (European evonymus)
- Alnus incana (grey alder)
- Salix alba (white willow)
- Betula alba (white birch)
- Populus tremula (aspen)

the following grasses and herbaceous plants were recommended by Vanicek:

- Elymus arenarius (European dune wildrye)
- Cynodon dactylon (Bermuda grass)
- Calama grostis epigeics (chee reed grass)
- Melilotus officienalis (melilot)
- Datura stramonium (thorn apple)
- Crambe maritima (sea kale).

Vaniček did not analyze the agricultural value of the vegetation. The characteristics of the ash were not presented.

Wagner reviews methods of the ash disposal and vegetative growth thereon in the German Democratic Republic [29]. He states that on the ash disposal at Rasitz (some 25 m high), a locust tree stand with some grasses has evolved naturally on a south - facing slope. On the remaining area poplars were planted in pits filled with compost of municipal (solid) wastes. Natural competitors to poplars were locust trees, willows and weeds (e.g. reeds, motherwort, melilot, tancy). The author recommends planting locust (Robinia pseudoacacia), mountain - ash (Sorbus aucuparia), lime (Tilia), cherry (Prunus arium), larch (Larix) and service (Gingko biloba). However, the author favours a covering of the surface with fertile soil and using the areas for domestic vegetable and flower gardens.

Hryncewicz and others previously attempted to plant vegetation on alkaline ashes in Halemba [11, 15] . Twenty - nine species were used (6 species of grasses, 7 legumes, 6 varieties of trees, and 5 of shrubs). The plants were cultivated on plots irrigated by a rill method, by subsurface irrigation, and by sprinkling machines. It appeared that the best pioneering plant was the white melilot (Melilotus alba) either alone or in combination with following grasses: Festuca rubra (creeping fescue), Dactylis glomerata (orchard grass), Lolium perenne (English bluegrass). Tests of trees and shrubs were disappointing.

RECLAMATION FOR AGRICULTURAL USE OF ASH DISPOSAL AREAS

Agricultural reclamation in Poland means technological and biological treatments carried out to prepare disturbed areas for future agricultursl production. Very often vegetative protection against wind erosion is identified as agricultural reclamation. This is so, only when this protection is achieved with vegetation that qualifies for an economic use (e.g. grasses or legumes with a good fodder usability, and with sufficient yield).The crops must be fit for animal consumption to be classified as agricultural crops.

According to Barber [3] , who conducted revegetation tests in alkaline ash (pH 8.5 and higher), the best growth was achieved using white melilot (Melilotus alba), while the growth of mixtures of grasses and legumes was relatively lower.

Interesting tests were carried out in Leeds (Gt. Britain) by Hodgson and others [10] . There the washes were found to be toxic by virtue of a high pH and a large concentration of borates. The use of sulphur, iron, aluminium sulphates, and sulphuric acid did not reduce alkalinity and did not improve the growth of vegetation. In regions where atmospheric precipitation is significantly greater than evaporation, the salts are leached. The reduction in dissolved boron is of considerable interest. A few species of plants tolerate boron in quantities of 20-30 ppm, but a majority of plants do not tolerate it.

The most radical method of agricultural reclamation is to cover the ash with a layer of soil. Greenhouse tests showed that various fertilizers can substitute to some degree for the soil, especially if species of plants that are resistant to toxic elements in ash are used. Highest yields were obtained with an "insulating" soil layer of 30 cm, by a simultaneous fertilization. When there is a shortage of soil, one can use substitutes such as the subsoil shale or peat. Sewage sludge gave negative results in the pot experiments due to the poor physical condition of the mixture. Field results were inconclusive. Bulky materials added to the ashes increase their sorption capacity and decrease the toxicity after 3 or 4 years. Later on their significance as a source of nutrients diminishes.

Particularly suitable in ameliorating detrimental properties of ashes are legumes since these diminish the boron concentrations. White melilot (Melilotus alba), has been used successfully.

Other nitrogen - fixing plants can also be used, particularly the Trifolium sp. and Medicago sativa.

Reports of a Czech investigator (Mr. Maly, [16, 17, 18] seem to be perfect from a point of view of methodology, however these concern weakly acid or neutral ashes of lignite. The tests involved the introduction of vegetation into a soil covering (thickness of 10-50 cm layers) placed on the ash. On plots fertilized with lime saltpetre (150 kg/ha) satisfactory growth was obtained with a mixture of sainfoin (Onobrychis viciaefolia) with grasses. However the grasses (tall oat grass - Avena elatior, creeping fescue-Festuca rubra), were experiencing strong competition from the sainfoin. Good growth was indicated, by English bluegrass (Lolium perenne), red meadow clover (Trifolium pratense), and bird's foot trefoil (Lotus corniculatus). The initial growth of creeping fescue (Festuca rubra) sheep's fescue (Festuca ovina), and white melilot (Melilotus alba) was initially satisfactory, but later on the growth of these species fell off.

In 1965-66, Maly carried out a series of experiments covering the ash surfaces with fertile soil of thicknesses of 10, 30 and 50 cm [17]. He adopted 3 crop rotation variants: a spring mixture alfalfa (Medicago sativa) a spring mixture of alfalfa and grass of cereal grains were planted in all cases for protection. Oats (Avena sativa), spring barley (Hordeum sativum), tall pea (Pisum sativum), and field pea (Pisum arvense) were used. The crop of green mass was highest (7.395 t/ha) on plots covered with the most soil (50 cm). The crop was somewhat smaller (5.889 t/ha) on plots with a 30 cm soil layer and was lowest (0.623 t/ha) on the control plot of ash. Maly states that crops depend also on the quality of the soil.

Hryncewicz and others [11] carried out tests introducing agricultural plants to the alkaline ash disposal at Halemba and obtained good crops of grasses (8.0 - 11.5 t/ha of green mass), and of spring barley (3.1 - 3.2 t/ha of grain), and also sufficiently good crops of fodder beetroots (25 - 32 t/ha of beets). The results were obtained with cultivation, organic and mineral fertilization, and with artificial watering.

In Northern Italy, (power plant Pietrafitta), fertile soil is spread on waste ash to a depth of 0.5 m, and the wheat is cultivated there after mineral fertilization; good crops are achieved there [7].

In summary, previously reported investigations of ash disposal utilization were limited to small tests, and it is not always clear what the characteristics of the ashes are and under what conditions the tests were performed. Hence the observations often seem incompatible, and there is no discussion of reasons for the differences.

DESCRIPTION OF ASH TREATMENTS FOR GREENHOUSE EXPERIMENTS USING PHYSICAL AND CHEMICAL AMENDMENTS

/Pot experiment I/

Table 1

Basic soil and no. of test	Applications of fertilizers N+P+K+Mg[x/] 1:0,8:1,2:0,5 1-single 2-double	Applications elements[x/] 1-single 2-double	Amendment treatments the growth of plants /w = pot/	Total weight of dry mass of material in pot Halemba/ Konin /kg/
1	2	3	4	5
light soil I	1	1	Control /no ash or amendments/	6.4
sterile, river sand II	1	1	Control /no ash or amendments/	6.9
ash				
III	none	none	none	3.6/2.3
IV	1	none	none	3.6/2.3
V	2	none	none	3.6/2.3
VI	1	1	none	3.6/2.3
VII	1	1	Low bog peat /31.4 g/w = 10 t/ha/	3.6/2.3
VIII	1	1	Low bog peat /31.4 g/w = 10 t/ha/+ + sulphur /10 g/w = 3.0 t/ha/	3.6/2.3
IX	2	2	Low bog peat /31.4 g/w = 10 t/ha/	3.6/2.3
X	1	1	Mountain peat /31.4 g/w = 10 t/ha/	3.6/2.3
XI	1	1	Mountain peat /31.4 g/w = 10 t/ha/ + sulphur /10 g/w = 3.0 t/ha/	3.6/2.3
XII	2	2	Mountain peat /31.4 g/w/	3.6/2.3
XIII	1	1	Shredded green mass from cereal plants /80.5 g/w = 25 t/ha/	3.6/2.4
XIV	1	1	Shredded green mass from legumes /80.5 g/w = 25 t/ha/	3.6/2.4
XV	1	1	Light sandy soil /25 % capacity/	5.5/3.9
XVI	1	1	Gypsum /3.14 g/w = 1 t/ha/	3.6/2.4
XVII	1	1	Sulphuric acid 1 n /125 ml/w = = 40 m3/ha/	3.6/2.4
XVIII	1	1	80 % maximal water capacity	3.6/2.4
XIX	1	1	Strong compacting of ash in pot	3.6/2.4
XX	1	1	Cover of surface with clay layer /1 cm/	3.6/2.4
XXI	1	1	Low bog peat /314 g/w = 100 t/ha/	4.0/2.7
XXII	1	1	Mountain peat /314 g/w = 100 t/ha/	2.9/1.9
XXIII	1	1	Shredded green mass from cereal plants /320 g/w = 100 t/ha/	3.2/2.0
XXIV	1	1	Shredded green mass from legumes /320 g/w = 100 t/ha/	3.1/2.4
XXV	none	none	Low bog peat /31.4 g/w = 10 t/ha/	3.6/2.4
XXVI	none	none	Mountain peat /31.4 g/w = 10 t/ha/	3.6/2.4
XXVII	none	none	25 % /by volume/ sterile river sand	5.4/4.4

[x/] Doses and forms of NPK Mg and of microelements are given in section [illegible]

FOREST RECLAMATION

Under the term "forest reclamation" is included the creation of timber-producing and recreational forests.

No thorough investigations of forest reclamation of waste ash disposal sites as such exist. Relatively lew attempts have been made to protect the surface through planting of trees and shrubs.

The experiments to establish tree stands and shrubbery on the disposals of ash and slags of bituminous coal made by Szczygieł and others [23] were the first ones, and have been discussed above. The tests made by the Soviet Union researchers [21, 24, 25, 26], in Czechoslovakia [16, 17, 18, 29] , in the German Democratic Republic [29] and in Poland [8, 22, 23] are also discussed.

Noteworthy are the observations made by Tarczewski [25, 26] of the introduction of organic life on ash disposal of the Ural power plants. They had shown that particular varieties of trees and bushes planted directly on ash extend their root systems even after 10 years.

Greszta and others [8] conducted tests of ash formed from lignite (pH 6-7) and from bituminous coal (pH 8.5 - 9.3). After 3 years of observation they stated that the locust tree, the poplar, the birch, the grey and black alders, the black currant and the tamarisk provided relatively good growth. The authors provide no detailed information regarding the method of neutralization, fertilization or vegetative growth.

The problem of forest reclamation cannot be considered as solved and requires further investigations. It seems advisable to consider local conditions as these can greatly alleviate difficulties of reclamation, which the papers seem to suggest [10, 30, 31, 32].

SECTION 5

THE OBJECT AND METHODOLOGY OF RESEARCH

GENERAL ASSIGNMENTS

The object of this research effort is the solution of the problem of stabilizing the surface of coal ash waste piles in order to: (1) minimize fugitive dust, and (2) reclaim the land surface for agricultural or forest use.

Since significant progress has been made in laboratory evaluations of ash stabilization as is noted in section 4, the principal emphasis of the effort herein described was field testing of a chemical-biological treatment procedure that would support agricultural uses of the land.

The subject of the research are alkaline waste ashes produced by burning bituminous coal and lignite coal in coal-fired electric generating facilities.

Two ash disposal sites were selected in Poland for this study. These were (fig. 38):

1) ash disposal for the power plant Halemba (bituminous coal ash); asd
2) ash disposal for the power plant Konin (lignite ash).

LOCATION OF THE RESEARCH WORK

Ash disposal for the power plant Halemba

Deposits of bituminous coal in Poland occur in the Upper Silesia Basin, in the Sudety Mts, and in the Lublin Basin. These coals are used for steam plants and thermal - electric facilities. Coal seams occur throughout the Namurian and Westfalian formations (upper carboniferous). The average content of ash in these coals ranges between 20 and 25 percent.

The investigations herein reported were conducted on the ash disposal of the power plant Halemba, which burns bituminous coal extracted from the Upper Silesian Basin (fig. 38). There are the wastes constituting a mixture of fly ash and bottom, formed from coal burring in granulating dust boilers. The portion of bottom ash does not exceed 5 percent of total waste material. Bottom ash and fly ash are removed from the power plant with hydraulic system. The mixture of fly ash is transported through pipelines to an impoundment situated 1.5 km from the plant. Deposition began behind 4-6 m dikes. Subsequently, the dikes have been raised to achieve a total height of 13 m. The area of the disposal is about 10 ha, and the quantity of ash deposited from 1962 through 1973 is about 2,000,000 m^3. The ash mixture was discharged along one side of the impoundment. Drainage wells were located along the opposite side. The water collected in the drainage wells was either discharged or reused in the hydraulic ash disposal system.

The ash disposal in Halemba is situated at an altitude of 245 m a.s.l., within the limits of co-called "Silesian Upland". Climatic conditions of this region are discussed later. One should note that the disposal is located in a strongly industrialized region, and the location did affect the results of the field tests to some extent.

DESCRIPTION OF ASH TREATMENTS FOR GREENHOUSE EXPERIMENTS
USING MINERAL FERTILIZERS
(Pot experiment II)

Table 2

No. of test	Basic soil	Fertilizers[x/]	Microelements[x/]	Additional substances changing composition or properties of ash
1	2	3	4	5
I	ash	none	none	none
II	ash	1/2(NPK Mg)	none	none
III	ash	1/2(NPK Mg)	1	none
IV	ash	NPK Mg	none	none
V	ash	NPK Mg	1	none
VI	ash	1/2 N	none	none
VII	ash	1/2 K	none	none
VIII	ash	1/2 P	none	none
IX	ash	1/2 Mg	none	none
X	ash	none	1	none
XI	ash	none	none	Low bog peat (3.5 g/pot = 10 t/ha)
XII	ash	none	none	Mountain peat (3.5 g/pot = 10 t/ha)
XIII	ash	none	none	Shredded green mass from cereal plants (8.9 g/pot = 25 t/ha)
XIV	ash	none	none	Shredded green mass from legumes (8.9 g/pot = 25 t/ha)
XV	ash	none	none	Sulphur (1.1 g/pot = 1 t/ha)
XVI	ash	NPK Mg (alkaline)	none	none

[x/] Doses and forms of NPK Mg and of microelements are given in section 6

Efforts to stabilize the top of the ash disposal at Halemba were successfully tried in 1972 through 1974. These efforts consisted of seeding with grasses and were discussed in preceeding section 4.

Ash disposal for the power plant Konin

Lignite deposits of recent tertiary age, characterized by a high (21-25 %) content of alkaline ashes, are found in the Wielkopolski Mining Region of Poland (fig. 38). The tertiary sediments consist of grey clays with alternating bands of silts, sands and gravels. Lignites occur within these sediments in extensive strata up to 10 m thick. The lignite formations are Miocene in age.

The field research has been conducted on the ash disposal for the Konin power plant, which is supplied with lignite extracted from the Konin mines. The coal is burned without any additives for improved combustion.

Due to varying sulphur contents in the coal coming from various open pits of the Konin mining complex, the coal is blended to achieve an average sulphur content.

The bottom ash and fly ash from electric precipitators are removed hydraulically to the sedimentation basins - as at the Halemba power plant. However, the impoundment dikes are only 4-6 m high due to unfavourable physical properties of the sediments.

The ash disposal area chosen for the field experiments is situated at an elevation of about 90 m a.s.l. in the central climatic sector, of Poland. A detailed description of the climatic conditions is provided in later sections of this report. The field site is located near both the power plant and an aluminium plant.

The surface area of waste ash is about 13 ha. At present it is used for additional ash disposal only sporadically. To protect the experimental area against further deposition of ash, it is surrounded

GERMINATION (SPROUTING) OBSERVED FOR VARIOUS CONTROL POTS AND ASH TREATMENTS USING PHYSICAL AND CHEMICAL AMENDMENTS

ASH FROM HALEMBA

(I experiment)

Table 3

No. of test	Added substances changing composition and properties of ashes in pots	Fertilizers x/		Number of seedlings (white mustard)		
		NPK Mg	Micro-ele - ments	Aug. 16	Aug. 17	Aug. 19
1	2	3	4	5	6	7
I	Control - Mineral soil	1	1	2	22	26
II	Control - Sterile sand	1	1	0	10	21
III	none	none	none	17	27	28
IV	none	1	none	21	28	28
V	none	2	none	20	27	28
VI	none	1	1	20	28	30
VII	Low bog peat (10 t/ha)	1	1	19	28	29
VIII	Low bog peat (10 t/ha) + 5	1	1	18	28	28
IX	Low bog peat (10 t/ha)	2	2	17	27	28
X	Mountain peat (10 t/ha)	1	1	18	27	28
XI	Mountain peat (10 t/ha)	1	1	13	28	29
XII	Mountain peat (10 t/ha)	2	2	22	28	29
XIII	Green cereal mass (25 t/ha)	1	1	14	26	27
XIV	green legume mass (25 t/ha)	1	1	17	26	27
XV	Light sandy soil	1	1	15	28	29
XVI	Gypsum (1 t/ha)	1	1	16	28	29
XVII	Sulphuric acid 1 n	1	1	15	27	29
XVIII	80 % max. water capacity	1	1	14	26	28
XIX	Strong compacting of ashes	1	1	14	26	28
XX	1 cm clay layer	1	1	0	13	21
XXI	Low bog peat (100 t/ha)	1	1	9	25	28
XXII	Mountain peat (100 t/ha)	1	1	23	24	24
XXIII	Green cereal mass (100 t/ha)	1	1	4	15	20
XXIV	Green legume mass (100 t/ha)	1	1	7	16	20
XXV	Low bog peat (10 t/ha)	none	none	28	30	30
XXVI	Mountain peat (10 t/ha)	none	none	27	28	28
XXVII	25 % sterile sand	none	none	26	28	29

x/ Fertilization according to table 1

by an ash dike. Revegetation experiments were performed prior to this project to stabilize the surface of adjoining ash disposal sites. However, due to the small thickness of a porous surface layer, the results were not promising and are not discussed here.

RESEARCH METHODS

The research program to stabilize ash and to permit future use of affected lands was divided into the following stages:

I - summary of previous tests and experiments made by various investigators concerning the properties of ash wastes affecting potentials for stabilization and revegetation;

II - verification through greenhouse "pot" test experiments of effects of adding soil amendments to alkaline ashes to improve growth conditions.

III - selection of promising soil amendment procedures from greenhouse tests and application to field plots;

IV - evaluation of effectiveness of various field treatments indirectly through photographic observations and directly through measurements of vegetation yields, of dynamics of the soil environment and of the utility of the vegetation; with reference to the planted trees and shrubs, evaluation of the effectiveness of various treatments through measurement of growth, of observations of hardiness and of changes in the growth medium.

The field and "pot" experiments were designed to provide guidance in reclaiming waste ash areas at other locations.

The details of the pedological, hydrogeological, climatic and biochemical investigations are discussed in subsequent sections of this report.

SECTION 6

THE PERFORMANCE OF "GREENHOUSE"(1) EXPERIMENTS

PREPARATIONS FOR THE EXPERIMENTS

The objective of these experiments was the determination of suitability of certain soil treatments, to effect favorable changes in the chemical and physical character of ashes in terms of supporting vegetation.

The experiments were carried out in an experimental agricultural station situated near Wrocław under conditions of ambient temperature and air and normal sunlinght, but a controlled water supply.

Samples of ash were taken from inactive disposal areas at Halemba and Konin, specifically, from the top 20 cm. During the time of sample collection (July, 1974) the surface of the wash was partially covered with loose, dry clumps of grass which remained from previous revegetation tests.

Soil treatment experiments were set up in accord with the method of independent series with one variable. Basic variants of experiment were the 20 treatments (Nos. I thru IX of table 1) which were conducted in four repetitions. Seven additional treatments (Nos. XXI thru XXVII in Table 1) were set up in two repetitions. Pots of treatment (light soil), and treatment (rinsed sterile river sand) were combined for the experiments. Weight of the "soil material" mass in particular pots in provided in table 1.

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(1) The experiments were carried out in a shelter which was not A "greenhouse" in terms of a controlled climate. Tests were conducted in small containers in a sheltered area.

White mustard (Sinapis alba L.) was used as a test plant of the variation "Borowska". This plant is characterized by its sensitivity to soil environment, and its continued growth during cooler seasons.

The first experiment (I) was carried out in pots of the Mitscherlich type with capacity of about 7 kg "soil". The moisture content of each test pot was maintained at 70 % of maximal capillary capacity, with exception of VIII treatment, where the content was maintained at 80 % of maximal capillary capacity. A single dose of fertilizer was added to all treatments except nos. III, XXV, XXVI and XXVII (table 1) the dose rate was:

- 1.0 g/pot N in the form of 20.5 % of ammonium sulphate
- 0.8 g/pot P_2O_5 in the form of 47.5 % of superphosphate
- 1.2 g/pot K_2O as K_2SO_4
- 0.5 g/pot MgO as $Mg\,SO_4 \cdot 7H_2O$.

The phosphatic and nitrogenous fertilizers were dosed in a stable form, the potassium and magnesium fertilizers in a water soluble form. Micro elements (nutrients) were added as follows:

- 1.0 mg/pot of Mo as $(NH_4)_6\ Mo_7O_{24} \cdot 4H_2O$
- 3.0 mg/pot of B as $2NaB_4O_7 \cdot 10H_2O$
- 3.0 mg/pot of Cu as $CuSO_4 \cdot 5H_2O$
- 5.0 mg/pot of Zn as $ZnSO_4 \cdot 7H_2O$
- 20.0 mg/pot of Mn as $MnSO_4 \cdot 5H_2O$
- 30.0 mg/pot of $FeCl_3 \cdot 6H_2O$.

An additional set of pots was established to ascertain the influence of particular macroelements on vegetation. One-half the dose rate of NPK Mg fertilizers used for the first twenty-seven treatments was used. Table 2 shows the experiment schemes for this second set of treatments.

Fig. no. 9. Greenhouse experiments – response of white mustard (Synapis alba) to mineral fertilization.

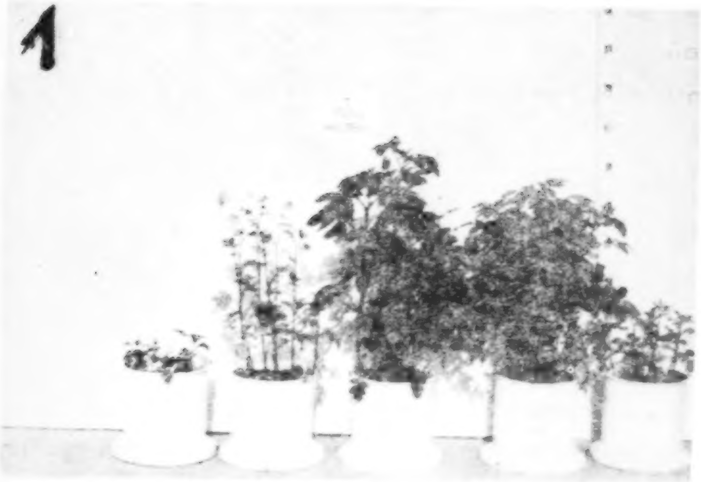

Fig. no. 10. Greenhouse experiments – growth of white mustard on ashes from Halemba; from left: control (II) – river sand + NPKMg + m; ash + 25 % of river sand; control (I) – light soil + NPKMg + m; ash + 25 % of mineral soil + NPKMg + m; control (III) pure ash (m=microelements).

Dose rates in the second set of treatments were as follows (calculated to 1 pot containing 0.6 dm^3 of ash):

Pure component	Dose rate in mg/pot		Type of fertilizer
	full rate	1/2 rate	
a) macro elements:			
all tests with exception of XVI:			
N	110	55	20.5 % ammonium sulphate
P_2O_5	90	45	47.5 % superphosphate
K_2O	130	65	K_2SO_4 chemically pure
MgO	60	30	$MgSO_4 \cdot 7H_2O$ chemically pure
test XVI			
N	110		NH_4NO_3 chemically pure
P_2O_5	60		K_3PO_4 " "
	30		47.5 % superphosphate
K_2O	130		$K_3P_2O_4$ chemically pure
MgO	60		$MgSO_4 \cdot 7H_2O$ chemically pure
b) micro elements:			
all tests:			
M_o	0.11		$(NH_4)_6 Mo_7O_{24} \cdot 4H_2O$
B	0.33		$Na_2B_4O_7 \cdot 10 H_2O$
Cu	0.33		$CuSO_4 \cdot 5 H_2O$
Zn	0.55		$ZnSO_4 \cdot 2 H_2O$
Mn	2.20		$MnSO_4 \cdot 5 H_2O$
Fe	3.30		$Fe(SO_4)_3$

THE WEATHER PROGRESS

The white mustard began to sprout on 16 Aug.74 and was harvested on 14 Oct. 74.

During the time of germination the air temperature was relatively high (average daily 20.3 to 26.8°C) and the humidity was low (11.3 mb

GERMINATION (SPROUTING) OBSERVED FOR VARIOUS CONTROL POTS AND ASH TREATMENTS USING PHYSICAL AND CHEMICAL AMENDMENTS

ASH FROM KONIN

(I experiment)

Table 4

No of object	Added substances changing composition and properties of ashes in pots	Fertilizer x/		Number of seedlings (white mustard)		
		NPK me	Micro-elements	Aug. 16	Aug. 17	Aug. 19
1	2	3	4	5	6	7
I	Control - Mineral soil	1	1	2	22	2
II	Control - Sterile sand	1	1	0	10	21
III	none	none	none	24	29	26
IV	none	1	none	17	26	26
V	none	2	none	[illegible]	23	27
VI	none	1	1	20	20	27
VII	Low bog peat (10 t/ha)	1	1	19	25	17
VIII	Low bog peat (10 t/ha) + S	1	1	13	16	[illegible]
IX	Low bog peat (10 t/ha)	2	2	4	12	10
X	Mountain peat (10 t/ha)	1	1	14	23	25
XI	Mountain peat (10 t/ha)	1	1	7	19	27
XII	Mountain peat (10 t/ha)	2	2	6	[illegible]	27
XIII	Green cereal mass (25 t/ha)	1	1	22	26	23
XIV	Green leguminous mass (25 t/ha)	1	1	16	22	21
XV	Light sandy soil	1	1	18	24	23
XVI	Gypsum (1 t/ha)	1	1	15	23	26
XVII	Sulphuric acid 1 n	1	1	17	22	21
XVIII	80 % max. water capacity	1	1	19	23	26
XIX	Strong compacting of ashes	1	1	16	26	26
XX	1 cm clay layer	1	1	1	13	22
XXI	Low bog peat (100 t/ha)	1	1	18	24	27
XXII	Mountain peat (100 t/ha)	1	1	25	21	26
XXIII	Green cereal mass (100 t/ha)	1	1	14	21	26
XXIV	Green legume mass (100 t/ha)	1	1	12	18	26
XXV	Low bog peat (10 t/ha)	none	none	25	30	30
XXVI	Mountain peat (10 t/ha)	none	none	24	26	26
XXVII	25 % sterile sand	none	none	24	26	26

x/ Fertilization according to table 2

partial pressure). This weather adversely influenced growth of small plants. Sunny and warm days in much of September advantageously influenced the vegetation of white mustard. By the end of September and in October average daily temperatures of air fell to between 6.0 and 9.0°C, accompanied by low humidity (0.7 to 3.5 mb).

In the first half of October ground frosts were observed. They did not have any evident effects on the vegetation of white mustard, as the pots were standing on push-carts at a height of 60 cm, under a glass roof of the shelter. However, fearing the occurrence of lower temperatures of air, the white mustard was cut on 14 Oct. 74.

PROGRESS OF GERMINATION IN THE FIRST GREENHOUSE EXPERIMENT

The white mustard was sown on 13 Aug. 74, 30 seeds to a pot at a depth of 2 cm. Germination was observed to range from 63 to 94 % (see tables 3 and 4). A large quantity of seeds was sown to ensure sufficient plants to measure differences in growth.

Sprouting began 3 days after sowing, i.e. on 16 Aug. 74. Their dynamics is shown in Tables 3 and 4.

On 29 Aug. 74 the number of individual plants in all experiment plots was reduced to 20 specimens (the smallest number in any repitition). During the period of germination on ashes collected from Halemba it was observed that the germinating seeds moved upward to within 0.5 to 1 cm of the surface. The seeds were separated from the soil, and during watering were often moved. This occurred until the plants were rooted.

In the case of ash from Konin, water percolated poorly into the ash mixtures. The surface ash agglomerated quite easily, and at a depth of 2 to 3 cm a compacted layer formed. Thus, root penetration was restricted. A number of plants sprouted without the seed-leafs.

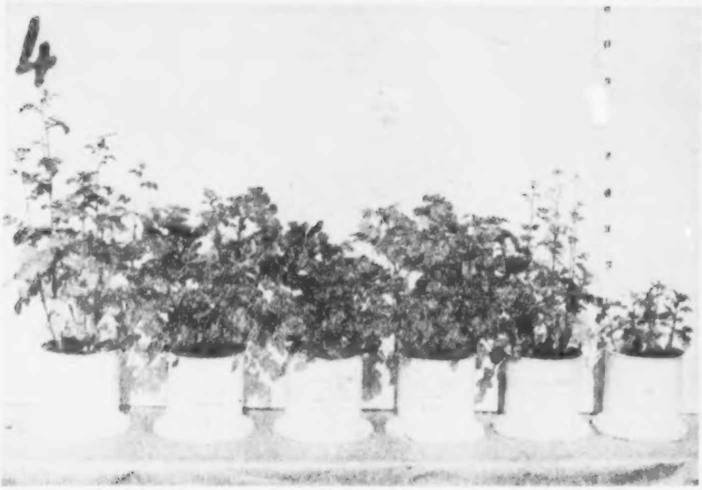

Fig. no. 11. Greenhouse experiments - growth of white mustard on ashes from Halemba; from left: ash + mountain peat + NPKMg + m; ash + mountain peat + 2 (NPKMg + m); ash + mountain peat + NPKMg + S; ash + mountain peat + NPKMg + m; ash + mountain peat; control (III) - pure ash (m = microelements).

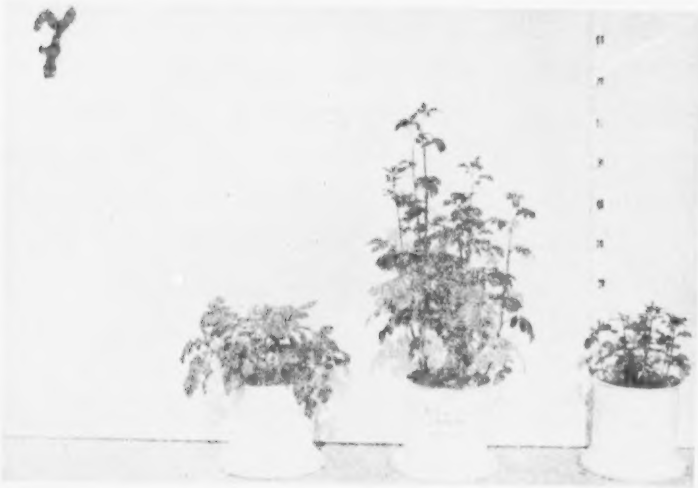

Fig. no. 12. Greenhouse experiments - growth of white mustard on ashes from Halemba; from left: ash + low moor peat + NPKMg + m + S; ash + low moor peat + NPKMg + m; control (III) - pure ash (m = microelements).

In cases the roots extended upward toward the surface, while the seed-leafs remained in the soil. One had to "fight" to keep each plant alive. This lasted for about 2 weeks, until the white mustard rooted itself more firmly.

On ashes from Halemba the greatest number of sprouts in the first day of visible germination was noted in pots of treatments XXV, (ash with low bog peat), XXVI, (ash with mountain peat), and XXVII (ash with river sand) (Table 3). In these variants no mineral fertilization was used. Only a few plants germinated in pots treated with high doses of green cereal mass (treatment XXIII), and alfalfa mass (treatment XXIV), or in those with dose of low bog peat (treatment XXI). In the following two days the germinations on majority of comparable variants became even, apart from the treatments II, XXIII and XXIV, where only about 2/3 of seeds germinated.

On ashes from Konin the greatest number of sprouts observed the first day of germination were for treatments III (pure ash), XXII (ash with mountain peat), XXV (ash with low mountain peat), XXVI (ash with mountain peat) and XXVII (ash with sterile sand). There was no mineral fertilization for all but treatment XXII. Retardation in germination occurred on ash with a 2 cm layer of clay (treatment XX), on ashes with double doses of macro - and microelements (treatments IX and XI) and on mountain peat with a sulphur addition (treatment XII). During the next two days the sprouting equalized with the exception of treatments II, IX and XX where germination was limited to about 2/3 of the seeds.

PROGRESS IN GERMINATION IN THE COMPLEMENTARY EXPERIMENT

White mustard was sown on 11 Aug. 74, 17 seeds to a pot, at depth of 2 cm. The dynamics of germination is shown in Tables 5 and 6. The first plant sprouts were observed on 15 Aug. 74.

On ash from Halemba, the germination was somewhat slower for those treatments of fertilizer and microelements and sulphur treatments

GERMINATION (SPROUTING) OBSERVED FOR VARIOUS CONTROL POTS AND ASH TREATMENTS EMPHASIZING MINERAL FERTILIZATION
(II experiment)

Bełchatów ash

Table 5

No. of treatment	Added substances changing composition and properties of ashes in pots	Fertilizer x/ NPK Mg	Micro-elements	Number of seedlings (white mustard) Aug. 16	Aug. 17	Aug. 18
1	2	3	4	5	6	7
I	none	none	none	12	13	14
II	none	1/2 NPK Mg	none	8	11	13
III	none	+	1	4	10	13
IV	none	1 NPK Mg	none	2	10	12
V	none		1	1	8	11
VI	none	1/2 N	none	2	10	14
VII	none	1/2 P_2O_5	none	5	12	14
VIII	none	1/2 K_2O	none	8	13	15
IX	none	1/2 MgO	none	10	14	14
X	none	none	1	4	10	14
XI	Low bog peat (10 t/ha)	none	none	10	12	14
XII	Mountain peat (10 t/ha)	none	none	10	14	15
XIII	Green cereal mass (10 t/ha)	none	none	8	11	13
XIV	Green legume mass (10 t/ha)	none	none	8	9	11
XV	Sulphur	none	none	0	6	12
XVI	Alkaline fertilizers	NPK Mg	none	1	7	10

x/ See table no. [illegible]

Konin ash

Table 6

No. of treatment	Added substances changing composition and properties of ashes in pots	Fertilizer x/ NPK Mg	Micro-elements	Number of seedlings (white mustard) Aug. 16	Aug. 17	Aug. 18
1	2	3	4	5	6	7
I	none	none	none	[illegible]	[illegible]	14
II	none	1/2 NPK Mg	none	2	10	12
III	none	+	1	4	[illegible]	13
IV	none	NPK Mg	none	[illegible]	[illegible]	[illegible]
V	none	+	1	[illegible]	4	[illegible]
VI	none	1/2 N	none	2	[illegible]	[illegible]
VII	none	1/2 K_2O	none	11	13	14
VIII	none	1/2 P_2O_5	none	11	14	
IX	none	1/2 MgO	none	9	11	14
X	none	none	1	11	12	14
XI	Low bog peat (10 t/ha)	none	none	12	13	14
XII	Mountain peat (10 t/ha)	none	none	11	13	14
XIII	Green cereal mass (10 t/ha)	none	none	9	14	14
XIV	Green legume mass (10 t/ha)	none	none	12	12	14
XV	Sulphur	none	none	[illegible]	[illegible]	14
XVI	Alkaline fertilizers	NPK Mg	none	[illegible]	[illegible]	10

II, III, IV, V, X, XV and XVI as well as for the treatment with alfalfa (XIV). One hundred percent germination was observed with treatments of phosphorus (treatment VIII) and mountain peat (XII).

On ash from Konin the best germination was achieved on most treatments using peat or certain fertilizers and with no amendments (I, II, VII, VIII, IX, X, XI, XII, XIII and XIV) while delayed germination was observed in cases of high fertilization.

DYNAMICS OF GROWTH OF WHITE MUSTARD IN THE FIRST GREENHOUSE EXPERIMENT

Beginning on 22 Aug. 74 the progressive growth of four selected plants in each pot was measured approximately every tenth day. In each successive measurement the same plants were observed. Results of these measurements are given in tables 7 and 8.

White mustard plants grew most prolifically on Halemba ashes treated with mountain peat and fully fertilized (treatment XXII (table 1). White mustard also did well in the early stages on ash treated only with peat (treatments XXV and XXVI). These two treatments supported fewer leaves and appear a paler green than those of treatment XXII in the later stages of growth; these peat treatments supported relatively little growth. Plants grown on ash treated with sand (treatment XXVII) showed similar dynamics of growth, the addition of 25 percent light soil with NPK Mg and microelements was successful (treatment XV). Plants growing on this treatment grew vigorously, were very well leafed and were dark green. Green mulch in small dose (treatments XIII and XIV) was suitable for white mustard. The same manure applied at a rate four times higher (treatments XXIII and XXIV) hindered growth and development. White mustard on plain ash grew well initially but after 2 weeks growth suddenly halted (treatment III). Double doses of mineral fertilizer (treatments V, IX and XII) hindered the growth of white mustard during the early stages of growth. Growth on these fertilized treatments was improved, but at the time of harvest the plant heights did not match the heights of the highest plants in other treatments. Additions of sulphur (treatments VIII and XI), restricted plant growth.

At the time of harvest (Oct. 14, 74), the white mustard was in different phases of development depending on the ash treatment. White mustard had shed blossoms and developed capsules in the soil (treatment I), on treatments with large amounts of mountain peat with NPK Mg (treatment XXII), on treatments with small amounts of mountain peat and no fertilizers (treatment XXVI) and treated ash with sand (treatment XXVII). White mustard was in full flower on plain ash (treatment III), treatments with a layer of clay (treatment XX), and on ash treated with low bog peat and no fertilizers (treatment XXV), white mustard had begun to flower on ash treated with the NPK Mg (treatmens IV), on ash treated with NPK Mg and microelements (treatment VI), on ash treated with peat (treatments VII and X), on ash treated with light soil and fertilization (treatment XV), on ash containing 80 percent maximum water capacity (treatment XVIII), on strongly compacted ash (treatment XIX) and on ash treated with large amounts of low bog peat (treatment XXI). From the remaining treatments the white mustard was collected at the bud-forming phase.

The Konin ashes appear to produce considerable diversification in growth and development of white mustard among the different treatments (table 8), vigorous growth (particularly in initial stage) was supported by plain ash (treatment III). Intensive growth also took place on ash treated with mineral fertilization and microelements (treatment VI), somewhat poorer growth occurred on ash treated with NPK Mg fertilizer (treatment IV). Double fertilization with NPK Mg (treatment V) retarded growth. Large doses of green mulch (treatments XXIII and XXIV), also halted the growth. The addition of light soil to ash (treatment XV) appeared favorable to growth. At the time of harvest flowers had developed on the white mustard only on plants growing on plain ash (treatment III). Flower buds did form on plants growing in ash treated with a single dose of NPK Mg fertilizer (treatment IV), as well

GERMINATION DYNAMICS OF WHITE MUSTARD GROWING ON ASH FROM HALEMBA
AVERAGE HEIGHT OF PLANTS IN CM - I EXPERIMENT

Table [illegible]

No of treatment	Added substances changing composition and properties of ashes in pots	Fertilizer (tab. 1)		Average height of plants (cm)					
		NPK Mg	Micro-elements	Aug. 10	Sep. 1	Sep. 11	Sep. 23	Oct. 4	Oct. 14
1	2	3	4	5	6	7	8	9	10
I	Control - mineral soil	1	1	1.7	11.7	19.2	37.6	57.9	64.[illegible]
II	Control - sterile sand	1	1	1.1	6.2	7.5	10.6	13.2	14.2
III	none	none	none	2.5	11.2	14.2	17.2	21.3	27.0
IV	none	1	none	2.8	12.3	19.4	35.2	46.8	56.3
V	none	2	none	2.4	6.8	13.2	29.6	44.4	53.1
VI	none	1	1	3.3	11.5	18.8	36.6	41.7	60.1
VII	Low bog peat (10 t/ha)	1	1	3.4	12.2	20.6	36.7	52.9	62.7
VIII	Low bog peat (10 t/ha) + S	1	1	3.7	9.1	11.8	19.7	36.0	42.9
IX	Low bog peat (10 t/ha)	2	2	3.2	7.7	8.8	18.3	32.0	43.2
X	Mountain peat (10 t/ha)	1	1	3.6	12.4	18.9	32.7	49.6	57.6
XI	Mountain peat (10 t/ha)	1	1	3.7	10.3	13.4	25.2	39.8	45.7
XII	Mountain peat (10 t/ha)	2	2	3.2	9.7	14.2	28.6	47.6	56.4
XIII	Green cereal mass (25 t/ha)	1	1	2.8	10.8	14.4	28.0	49.0	58.8
XIV	Green legume mass (25 t/ha)	1	1	3.4	12.0	17.2	32.0	53.8	62.3
XV	Light sandy soil	1	1	2.7	13.2	19.5	35.3	54.8	62.2
XVI	Gypsum (1 t/ha)	1	1	3.0	11.4	16.4	31.6	46.8	51.7
XVII	Sulphuric acid 1 n	1	1	2.8	12.0	18.7	30.5	45.0	49.4
XVIII	80 % max. water capacity	1	1	2.8	12.7	21.0	41.4	57.6	62.2
XIX	Strong compacting of ashes	1	1	2.6	11.8	19.3	36.6	52.2	57.4
XX	1 cm clay layer	1	1	1.8	11.9	20.8	39.2	53.8	60.8
XXI	Low bog peat (100 t/ha)	1	1	1.9	10.3	18.3	38.8	57.4	63.6
XXII	Mountain peat (100 t/ha)	1	1	2.8	20.2	28.8	41.2	59.5	69.7
XXIII	Green cereal mass (100 t/ha)	1	1	1.2	5.5	8.4	17.4	30.8	37.1
XXIV	Green legume mass (100 t/ha)	1	1	1.4	4.6	6.5	11.8	21.7	24.9
XXV	Low bog peat (10 t/ha)	none	none	2.9	17.1	25.3	25.8	40.2	45.4
XXVI	Mountain peat (10 t/ha)	none	none	3.0	15.7	32.2	30.6	45.9	51.6
XXVII	25 % sterile sand	none	none	2.6	15.1	20.[illegible]	28.2	41.1	56.4

GERMINATION DYNAMICS OF WHITE MUSTARD GROWING ON ASH FROM KONIN
AVERAGE HEIGHT OF PLANTS IN CM - I EXPERIMENT

Table 8

No. of treat-ment	Added substances changing composition and properties of ashes in pots	Fertilizer (tat. 1)		Average height of plants (cm)					
		NPK Mg	Micro-elements	Aug. 22	Sep. 1	Sep. 11	Sep. 23	Oct. 4	Oct. 14
1	2	3	4	5	6	7	8	9	10
I	Control - mineral soil	1	1	1,7	11,7	19,2	37,6	57,9	[illegible]
II	Control - sterile sand	1	1	1,1	6,2	7,5	10,6	13,3	[illegible]
III	none	none	none	2,6	12,4	16,9	30,0	44,1	[illegible]
IV	none	1	none	1,6	6,8	10,1	23,8	38,9	[illegible]
V	none	2	none	1,0	4,2	4,8	6,4	6,4	7,6
VI	none	2	1	1,6	7,5	11,8	28,6	[illegible]	[illegible]
VII	Low bog peat (10 t/ha)	1	1	1,9	8,9	14,3	30,7	[illegible]	[illegible]
VIII	Low bog peat (10 t/ha) + S	1	1	1,4	4,6	5,5	6,7	[illegible]	11,4
IX	Low bog peat (10 t/ha)	2	2	0,9	4,3	5,3	7,3	[illegible]	16,7
X	Mountain peat (10 t/ha)	1	1	1,6	6,8	9,6	18,6	[illegible]	[illegible]
XI	Mountain peat (10 t/ha)	1	1	1,2	5,2	5,7	6,9	[illegible]	10,8
XII	Mountain peat (10 t/ha)	1	1	0,9	3,7	4,5	5,4	6,8	[illegible]
XIII	Green cereal mass (25 t/ha)	1	1	1,8	6,8	8,2	26,4	[illegible]	[illegible]
XIV	Green legume mass (25 t/ha)	1	1	1,6	6,5	8,5	17,1	[illegible]	[illegible]
XV	Light sandy soil	1	1	1,5	7,2	11,0	25,9	[illegible]	[illegible]
XVI	Gypsum (1 t/ha)	1	1	1,5	5,2	6,0	14,6	19,0	23,0
XVII	Sulphuric acid 1 n	1	1	1,6	5,7	8,1	16,5	23,8	25,0
XVIII	80 % max. water capacity	1	1	1,2	4,9	6,1	10,2	14,4	17,6
XIX	Strong compacting of ashes	1	1	2,0	6,2	7,5	11,3	17,8	22,4
XX	1 cm clay layer	1	1	1,1	7,2	13,4	28,3	35,3	42,3
XXI	Low bog peat (100 t/ha)	1	1	1,7	6,2	8,8	16,8	28,2	34,8
XXII	Mountain peat (100 t/ha)	1	1	2,0	7,8	11,9	28,0	34,2	45,2
XXIII	Green cereal mass (100 t/ha)	1	1	1,0	4,3	4,8	5,6	7,5	8,4
XXIV	Green legume mass (100 t/ha)	1	1	1,0	4,0	4,3	4,9	5,2	5,6
XXV	Low bog peat (10 t/ha)	none	none	1,9	6,6	8,8	15,8	23,0	27,4
XXVI	Mountain peat (10 t/ha)	none	none	1,6	6,8	8,4	16,2	24,2	28,9
XXVII	25 % sterile sand	none	none	1,6	6,8	9,4	17,6	25,6	33,8

as with an ash treated with macro- and microelements (treatment VI), with a small dose of peat (treatments VII and X), with a small dose of green cereal mulch (treatment XIII), and with mineral soil (treatment XV), and on acidified ash (treatment XVII), strongly compacted ash (treatment XIX), ash covered with layer of clay ash (treatment XX), on ash treated with large doses of peat (treatments XXI and XXII), and ash treated with small doses of peat without fertilization (treatments XXV and XXVI). White mustard was harvested for the remaining treatments at a time when the plants had formed two to four pairs of mature leaves.

DYNAMICS AND GROWTH OF WHITE MUSTARD IN SECOND GREENHOUSE (COMPLEMENT) EXPERIMENT ECHAMINING THE EFFECT OF FERTILIZATION

Starting from the Aug. 22, 74 the height of four plants was measured periodically as in the previously-described experiment.

White mustard initially grew best, in the case of ashes from Halemba on ash treated with a single dose of phosphorus (treatment VIII), of magnesium (treatment IX), and of potassium (treatment VII. However after [illegible] days (Aug. 28, 74) the plants growing on ash treated with peats (treatments XI and XII) supported equivalent growth. The addition of sulphur (treatment XV) retarded growth. To a smaller extent, the addition of alkaline mineral fertilizers (treatment XVI) also retarded growth. Ashes treated with full doses of physiologically acid mineral fertilizers (treatments IV and V) supported less growth in the early stages than in the later stages of growth. Ash treatments with full doses of fertilizers supported darker green foliage but, development was somewhat delayed. Treatment with microelements only (treatment X), supported plant growth similar to that on ash with no amendments (treatment I), which signifies, that the microelements are not essential for growth of plants in this type of ashes.

At the time of harvest, the plants growing on Halemba ash treatments were in different development phases. White mustard was forming capsules on ashes treated with fertilizers (treatments VI, VII, VIII, IX). Plants with additions of phosphorus were observed to flower earliest. On ash with additions of sulphur (treatment XV) the plants had not formed flower buds at the time of harvest.

In the case of ashes from Konin white mustard growth was consistently vigorous on ash treated with phosphorus (treatment VIII), and with magnesium (treatment IX). Ash fertilized with potassium only (treatment VII), also supported good growth. The poorest growth was observed on ash treated only with nitrogen (treatment VI). Addition of half doses of mineral fertilizers to the Konin ash initially hampered the growth of white mustard, later on however the growth rate increased. Addition of microelements similarly hampered the growth of white mustard (treatment III). On ash with full dose of macroelements, with or without microelements the growth of white mustard was consistently hindered from the start through to the time of harvest. Addition of sulphur clearly halted growth (treatment XV).

At the time of harvest white mustard had formed capsules on ash fertilized with potassium only (treatment VII), phosphorus only (treatment VIII), magnesium only (treatment IX), with microelements only (treatment X), and on ash treated with green cereal manure (treatments VII, VIII, IX and XIII, respectively). Plants on the remaining treatments were delayed in development. White mustard was gathered while blossoming from treatments IV (NPK Mg fertilization), V (fertilization with macro- and microelements) and XV (fertilization with sulphur).

Generally the growth of plants on ashes from Halemba was much better than on ashes from Konin.

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[illegible]

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	2	3	4	5	6	7	8	9	10	11	12	13
				[illegible]								
III	none	none	none	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
VI	none	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
VII	[illegible] peat [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	
X	[illegible] peat [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
XIII	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
XIV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
XV	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
S	[illegible]	none	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]
				[illegible]								
III	none	none	none	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
VI	"	1	1	[illegible]	[illegible]	[illegible]		[illegible]	700	[illegible]	[illegible]	
VII	[illegible] peat [illegible] t/ha)	1	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	800	[illegible]	[illegible]	
X	[illegible] peat [illegible] t/ha)	1	1	1300	[illegible]	100	[illegible]	1500	100	30	[illegible]	
XIII	Green cereal mass (2[illegible] t/ha)	1	1	[illegible]	[illegible]	0	400	1400	100	10	[illegible]	
XIV	Green legume mass (25 t/ha)	1	1	2300	800	200	700	1200	200	100	60	
XV	Light sandy soil	1	1	1200	300	200	700	1200	30	70	560	
S	Sulphur	none	none	600	200	800	0	600	300	120	510	

x/ Extinction measurement of light passed through chlorophyl extracted from algae.

ACTIVITY OF SOME PHYSIOLOGICAL GROUPS OF MICROORGANISM IN POT EXPERIMENT
(IN THOUSANDS)

Table 10

[illegible]	Added substances changing composition and properties of water in pots	Fertilizer (tab. 1)		Number of microbes (in thous/1 g. of soil)			Nitrogen bacteria	Microorganism fixing atmospheric nitrogen - (% glucose loss)	Nitrification (mg of NO_3)	Cellulose decomposition (% cellulose loss)
		NPK Mo	Micro-elements	Antibiotic		Proteolytic				
				Bacteria	Fungi	Bacteria				
1	2	3	4	5	6	7	8	9	10	11
				HALEMDA						
[illegible]	none	none	none	[illegible]	[illegible]	69	0	8,35	11	[illegible]
[illegible]	none	1	1	[illegible]	5.2	164	0	13,20	20	1
[illegible]	[illegible] peat (10 t/ha)	1	1	[illegible]	[illegible]	268	0	16,10	12	4
[illegible]	[illegible] peat (15 t/ha)	1	1	60	[illegible]	144	0	5,30	[illegible]	7
[illegible]	[illegible] mass (25 t/ha)	1	1	[illegible]	[illegible]	[illegible]	0	20,12	[illegible]	16
[illegible]	[illegible] mass (25 t/ha)	1	1	[illegible]	[illegible]	173	0	20,80	40	15
[illegible]	Light sandy soil	1	1	[illegible]	[illegible]	178	0	13,60	128	18
[illegible]	[illegible]	none	none	[illegible]	[illegible]	12	0	6,3	[illegible]	18 (none)
				[illegible]						
[illegible]	none	none	none	[illegible]		8000	0	1320	[illegible]	17000
[illegible]	none	1	1	8000		11500	0	1250	18000	19000
[illegible]	[illegible] peat (15 t/ha)	1	1	[illegible]		12900	0	1620	[illegible]	16000
[illegible]	[illegible] peat (15 t/ha)	1	1	[illegible]		16000	0	1520	[illegible]	28000
[illegible]	[illegible] mass (25 t/ha)	1	1	[illegible]		[illegible]	0	[illegible]	[illegible]	16000
[illegible]	[illegible] mass (25 t/ha)	1	1	[illegible]		[illegible]	0	[illegible]	12000	14000
[illegible]	Light [illegible] soil	1	1	[illegible]		12100	0	[illegible]	[illegible]	[illegible]
	[illegible]	none	none	[illegible]		[illegible]		[illegible]	[illegible]	34000

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OBSERVATIONS OF PLANT VIGOR

Ashes from Halemba

Plants (white mustard) growing on all ash treatments that did not have additions of NPK Mg, yellowed during the early stages of growth, and the bottom leaves dried (treatments III, XXV, XXVI, XXVII - table 1). Leaves of these plants were also smaller, lighter in colour and fewer in number than on plants growing in fertilized treatments. From the moment of germination plants growing on ash treated with sulphur were not healthy. Their stems turned violet, and this colour stayed until the time of harvest. The stems narrowed close to the roots. As a result, the plants bent over and twisted. In addition, the leaves assumed a tesselated (mosaic pattern of square blocks) colouring, and then necrotic stains. Not until the end of September had these plants started to form flower buds. Treatments with green mulch (treatments XIII, XIV, XXIII and XXIV) of table 1 produced plants which showed a lack of vigor in the early stages of growth. These plants had shrivelled small leaves. These symptoms occurred particularly strongly on treatments with a large dose of green manure (treatments XIII and XIV), where the sprouts were weaker, and plants were very small. However on treatments with a small dose of green manure, the white mustard overcame illiness, grew vigorously and was well-leafed.

In the experiment described in table 2, leaves began to yellow and dry out early (Sep. 2, 74) on white mustard growing on plain ash (treatment I - table 2), on ash treated with microelements (treatment X), and on all ashes with no nitrogen added (treatments VII, VIII, IX, XI and XII). After treatments with NPK Mg (treatments II and III) and especially with a full dose (treatments IV and V), the plants consistently were green and their leaf blades were larger than on other treatments. The leaves of plants growing on ash treated with alkaline fertilizers (treatment XIV), had a tesselated pattern and the edges began to yellow (but did not dry out). White mustard on ash treated with sulphur turned violet, the plants narrowed near the root neck, were twisted and were

ENZYME ACTIVITY OF ASHES IN POT EXPERIMENT

Table 11

№ of treatment	Added substances changing composition and properties of ashes in pots	Fertilizer (tab. 1)		Enzyme determination		
		NPK Mg	Micro-elements	Proteinases (% of decomposed gelatine)	Urease mg of NH_4^+ per 1 g of soil	Saccharase mg of converted sugar per 1 g of soil
1	2	3	4	5	6	7
		HALEMBA				
III	none	none	none	42	0,26	0,24
VI	none	1	1	58	0,65	0,36
VII	Low bog peat (10 t/ha)	1	1	52	0,65	0,84
X	Mountain peat (10 t/ha)	1	1	32	0,65	0,24
XIII	Green cereal mass	1	1	70	0,78	0,84
XIV	Green legume mass	1	1	86	0,65	1,2[illegible]
XV	Light sandy soil	1	1	60	0,78	0,96
S	Sulphur	none	none	36	0,13	2,16
		KONIN				
III	none	none	none	30	0,39	0,24
VI	none	1	1	27	0,82	[illegible]
VII	Low bog peat (10 t/ha)	1	1	74	0,81	0,60
X	Mountain peat (10 t/ha)	1	1	40	0,65	[illegible]
XIII	Green cereal mass	1	1	4[illegible]	[illegible]	[illegible]
XIV	Green legume mass	1	1	37	[illegible]	[illegible]
XV	Light sandy soil	1	1	100	[illegible]	[illegible]
S	Sulphur	none	none	[illegible]	[illegible]	[illegible]

poorly held in the ground, and about 60 percent of them perished, growing in a mulch similar to that occurring on the same treatments described in table 1.

The ashes from Konin

Wherever white mustard was hampered in its growth on Konin ash, regardless of the treatment, the leaves assumed a chlorotic colouring. The leaves were small, few in number, and often dried out along the edges. In the experiment described on table 1, these symptoms occurred wherever a double dose of mineral fertilization had been applied (treatments V, IX and XII - table 1), (treatments VIII and XI) where ash was treated with both types of peat and with addition of sulphur, on ash treated with large doses of green mulch (treatments XXIII and XIV). Plants growing on treatments with sulphur (VIII and XI), had a strong violet colouring in the stems in addition to a narrowing of the stems near the roots, accompanied by abnormal bending of the plants - a condition similar to that observed in similar treatments (with sulphur) of ash from Halemba.

In the fertilizer experiment II (table 2) illness symptoms appeared only on white mustard growing on ash treated with sulphur. The plants on this treatment did not grow, the stalks turned violet, the root narrowed and the plant subsequently bent over and was twisted. A tesselated colouring pattern was observed on the leaves.

WATER CONSUMPTION

During the 60 - day period growth(approximately) of white mustard, the water consumption of plants and for evaporation from the surface of ashes varied widely for various ash treatments (fig. 33). Consumption depended mainly (but not exclusively) on the size and mass of the plants. The greatest water consumption was measured in treatments where the capillary water capacity was maintained at 80 percent of maximum (treatment XVIII - table 1). The smallest consumption occurred on ash treated with sand (treatment table 1).

YIELD OF WHITE MUSTARD FOR ASH TREATMENT DESCRIBED IN TABLE 1

(1 greenhouse experiment)

Table 12

No. of treat-ment	Added substances changing composition and properties of ashes in pots	Fertilizer (tab. 1)		Halemba		Konin	
		NPK Mg	Micro-ele-ments	Average crop of green mass (g/pot)	Average crop of dry mass (g/pot)	Average crop of green mass (g/pot)	Average crop of dry mass (g/pot)
1	2	3	4	5	6	7	8
I	Control - Mineral soil	1	1	239,8	14.8	239,8	14,8
II	Control - Sterile and	1	1	11,4	22,8	11,4	22,8
III	none	none	none	20,6	21.4	107,6	14,5
IV	none	1	none	150,6	17.0	116,5	13,2
V	none	2	none	175,9	15,0	3,9	15,4
VI	none	1	1	160,2	15.5	148,0	13,8
VII	Low bog peat (10 t/ha)	1	1	169,8	17.1	152,2	13,9
VIII	Low bog peat (10 t/ha) + S	1	1	119,9	14.1	8,6	14,0
IX	Low bog peat (10 t/ha)	2	2	126,5	11,8	22,0	10,9
X	Mountain peat (10 t/ha)	1	1	179,9	15.7	108,3	13,1
XI	Mountain peat (10 t/ha)	1	1	141.9	13,5	5,8	15,5
XII	Mountain peat (10 t/ha)	2	2	194.4	13,0	6,9	11,6
XIII	Green cereal mass (25 t/ha)	1	1	218,9	12,2	115,4	11,9
XIV	Green legume mass (25 t/ha)	1	1	230,1	12,1	58,9	11,4
XV	Light sandy soil	1	1	199.4	14,3	117,2	13,0
XVI	Gypsum (1 t/ha)	1	1	171,4	13,8	40,7	12,3
XVII	Sulphuric acid 1 n	1	1	148,1	16,4	64,6	14,7
XVIII	80 % max. water capacity	1	1	205.4	14,7	23,8	12,6
XIX	Strong compacting of ashes	1	1	176,4	16,3	39,5	12,6
XX	1 cm clay layer	1	1	173,1	18,2	115,2	15,7
XXI	Low bog peat (100 t/ha)	1	1	226,5	15,4	76,0	14,5
XXII	Mountain peat (100 t/ha)	1	1	131,5	21,1	122,2	15,2
XXIII	Green cereal mass (100 t/ha)	1	1	104,5	11,6	3,8	21,0
XXIV	Green legume mass (100 t/ha)	1	1	46,2	10,4	2,0	18,2
XXV	Low bog peat (10 t/ha)	none	none	64,8	21,6	48,0	15,0
XXVI	Mountain peat (10 t/ha)	none	none	59,5	19,4	50,5	14,3
XXVII	25 % sterile sand	none	none	52,2	21,4	63,2	14,1

Ashes from Halemba

The water consumption was reduced where plant growth was limited. Therefore, water consumption was low where mineral fertilizers were lacking (treatment III, table 1) and where sulphur was added (treatments VIII and IX). The addition of small quantities of green mulch (treatments XIII and XIV), particularly cereal grains (treatment XIII) caused a decrease in evapotranspiration despite relatively high yields of white mustard.

Ashes from Konin

Water consumption on ash was generally lower than on mineral soil (treatment I - table 1). Relatively high consumption was noted on ash mixed with soil (treatment XV), while a little less consumption occurred on pure ash (treatment III), and on ash fertilized with macro- and microelements (treatment VI). However crops grown on treatment VI exceeded those on treatment III by more than 40 percent. Maintenance of ash at a high soil moisture content (treatment XVIII) adversely affected the size of the plants. Nonetheless water consumption equalled water consumption on treatment III. Minimal crops of white mustard grew on treatments XXIII, XXIV, and thus water consumption amounted to only 57 percent of that observed for treatment.

BIOLOGICAL ACTIVITY OF ASHES IN GREENHOUSE EXPERIMENTS

Selected ash treatments were examined for biological activity. Untreated ash (III - table 1) was used for control. The other treatments analyzed were (table 1) ash treated with NPK Mg and microelements (VI), ash treated with peat (treatment VII and X), ash treated with green mulch (treatments XIII and XIV) and ash treated with sulphur (treatment XV - table 2).

The following analyses were performed:

YIELD OF WHITE MUSTARD FOR ASH TREATMENTS DESCRIBED IN TABLE 2

(II greenhouse experiment)

Table 13

No of treatment	Added substances changing composition and properties of ashes in pots	Fertilizer (tab. 2)		Halemba		Konin	
		NPK Mg	Micro-elements	Average crop of green mass (g/pot)	Average crop of dry mass (g/pot)	Average crop of green mass (g/pot)	Average crop of dry mass (g/pot)
1	2	3	4	5	6	7	8
I	none	none	none	15,5	3,4	34,2	5,3
II	none	1/2 NPK Mg	none	22,2	5,1	38,7	6,8
III	none	1/2 NPK Mg	1	18,0	4,0	33,2	5,0
IV	none	1 NPK Mg	none	23,8	5,1	18,6	2,3
V	none	1 NPK Mg	1	25,0	4,8	24,6	3,5
VI	none	1/2 N	none	23,6	4,0	29,9	4,3
VII	none	1/2 K_2O	none	15,1	4,1	34,2	5,9
VIII	none	1/2 P_2O_5	none	14,6	2,8	43,1	7,4
IX	none	1/2 MgO	none	15,2	3,7	43,1	7,0
X	none	none	1	14,1	3,1	41,1	6,6
XI	Low bog peat (10 t/ha)	none	none	17,6	3,9	36,7	6,0
XII	Mountain peat (10 t/ha)	none	none	17,0	3,9	33,6	5,2
XIII	Green cereal mass (10 t/ha)	none	none	19,9	4,4	38,6	6,8
XIV	Green legume mass (10 t/ha)	none	none	21,8	4,9	35,9	6,5
XV	Sulphur	none	none	6,6	1,7	4,2	0,6
XVI	Alkaline fertilizers	NPK Mg	none	19,0	3,2	40,2	6,3

I - identification of microorganisms present in ash based on accelerated growth in selected nutrients itemized below:

I-1) extractions from investigated soils (subsoil approximated to natural conditions), affording a development of bacteria and fungi;

I-2) Conn with ammonia nitrogen to identify bacteria, especially of actinomyces and fungi benefiting from this form of nitrogen [39];

I-3) denotation of the number of fungi using neutral red and chloram - phenicol which halts the development of bacteria according to method of Martins [44];

I-4) determination of algae present according to method of Bristol [38];

II - Denotation of the activity of the basic physiological groups of microorganism activity by:

II-1) the rank value of amylolythic microbes growing on potato agar after application of Lugol reagent [36];

II-2) the rank value of proteolythic microbes growing in a gelatinous base according to the method of Frazier [36];

II-3) the rank value of Azobacter growing on agar base in fluid nourishing substance of Ashby [37] using the gland method;

II-4) activity of microorganisms fixing nitrogen in fluid nourishing substance of Ashby expressed in per cent of glucose consumption [37];

II-5) nitrification intensity in Winogradzki [45] nourishing substance on the basis of quantity of nitrite nitrogen formed;

II-6) decomposition of cellulose by microbes in terms of percent cellulose loss [42].

III - Determination of enzyme activity of ashes by:

III-1) saccharose according to Hofmann and Seegerer [40];
III-2) urease according to Hofmann and Schmidt [40];
III-3) proteinases according to Hofmann and Niggeman [40].

The results of investigations are presented in tables 9, 10 and 11.

Ash from Halemba

The results of microbiological analyses indicate a low biological activity in ash from Halemba in comparison with the control samples of cultivated soil control (tables 9, 10 and 11).

Treatment of ashes with mineral and organic substances produced changes in biological activity. The greatest increase in biological activity occurred in ash treated with alfalfa (treatment XIV, table 1) and cereal grains (treatment XIII). This indicates the presence of large numbers of bacteria, of actinomyces and of algae, on the substance added.

Treatment with peat produced a relatively smaller increase in biological activity, though high moor peat seems to be better than low moor peat (treatment X). None the less some microbe groups fared better in more mineralized low moor peat (microorganisms utilizing ammonia nitrogen combinations in Conn nourishing substance).

Mixing ash with light soil (treatment XV) improves "soil" conditions in terms of supporting bacteria to a level approaching that of high moor (mountain) peat treatment (treatment X). Treatment with light soil improves nitrification.

Addition of sulphur decreased biological activity in terms of bacteria, yet increased the number of fungi.

Ash from Konin

Microbiological measurements made during the greenhouse experiment, indicate an average biological activity of ashes from Konin in comparison to the activity of cultivated light soils. This ash has more organic matter.

Enrichment of ash with low moor peat (treatment VII - table 1) or mineral fertilizers (treatment VI), caused an increase in microorganisms (table 9) and consequently greater enzyme activity (table 11).

Treatment of ash with green plants mulch (treatments XIII and XIV), and of high moor peat (treatment X) decreased the numbers of microorganisms in the ash (table 9). The treatments also adversely affected conditions for enzyme production (table 11).

Treatment with light soil (treatment XV) improved conditions for nitrification and increased enzyme activity. Introduction of sulphur (treatment XV - table 2) produced deteriorated conditions for enzyme production.

YIELDS IN VEGETATION EXPERIMENTS

The production of white mustard was measured three times on Sep. 2, on Sep. 11 (control crops) and on Oct. 14, 74 (final harvest). Table 12 presents the average yields for the harvests.

Ashes from Halemba

The weights of green and dry mass produced by ash treatments listed in table 1 are compiled in table 12. The highest weight yields were achieved on the control of mineral soil (treatment I). The yields of white mustard grown on plain ash without fertilization (treatment III) were exceptionally low. Treatment with a single NPK Mg dose (treatment IV) increased crops seven-fold. Supplementing this fertilizer with microelements (treatment VI) further increased in yields by about 6 percent. On the series of ashes fertilized exclusively with mineral fertilizers, the highest yields were achieved with the double dose of NPK Mg (treatment V) despite the fact that plants initially grew poorly, and were not particularly tall at the time of harvest.

In the case of treatments with small amounts of peat, the yields were supported by high moor peat (treatment XII). But in the case of high rates of peat applications, better yields were supported by low moor peat (treatment XXI). Treatments with peat and no mineral fertilizers (treatments XXV and XXVI) appeared insufficient for the plants, and yields were small.

Greens in smaller amounts produced higher yields than did peat. Yields of white mustard growing on ash fertilized with MPK Mg and green mulch were essentially equal to the yield obtained from the control of mineral soil. However, large doses of green mulch reduced yields. Treatment with light soil and NPK Mg (treatment XV) supported good yields.

"Acidification" of ashes with sulphuric acid, sulphur, or with gypsum, (treatments XVII, VIII and XI, XVI), produced poorer yields.

High yields of green mass were achieved on ash treated with soil (treatment XV), on ash covered with layer of clay (treatment XX) and on compacted ash (treatment XIX).

In the experiment conducted to determine the effect of fertilizers (described in table 2) the highest yield of white mustard (green mass) was obtained on ash treated with mineral fertilizers and microelements (treatment V, table 13). Smaller doses of macro- and microelements produced smaller increases in yields. The highest yield of dry mass of white mustard was measured on ash supplemented with NPK Mg (treatments II and IV). Addition of microelements diminished the yield.
Of those treatments involving mineral fertilizers in single doses, the highest increase green mass was measured on ash treated with nitrogen (treatment VI). The highest yield of dry mass was supported by ash treated with potassium (treatment VIII). Crops of green and dry mass on ash treated with sulphur (treated XV) were about 50 percent lower than supported by the control pot (I).

Ashes from Konin

A relatively high yield of white mustard was obtained on untreated Konin ash (table 12 - treatment III). However treatments with single doses of macro- and micro-elements increased the yield of green mass by 40 percent (treatment VI) over that of untreated ash. A somewhat lower yield was produced on ash treated with NPK Mg (treatment IV). Single dose treatments with macro- and microelements increased the yield of green mass by 40 percent (treatment VI). A somewhat lower yield was supported by ash treated with NPK Mg (treatment IV). Double doses of macro- and micro-elements visibly halted the growth of white mustard, and the yields were lowest (treatment V). Treatment with mineral soil supported higher yield resembling those of treatment VI.

Low moor peat combined with macro- and microelements gave the highest yield of all the treatments of Konin ash. Large amounts of green manures (treatments XXIII and XXIV) and treatments with sulphur (treatments VIII and XI) restricted growth of white mustard as did the treatments with gypsum and with sulphuric acid (treatments XVI and XVII).

Yields of green mass on ash treated with peat and with double doses of mineral fertilizers were low.

In the fertilizer experiment (table 13) the highest yields of green and of dry mass were supported by ash treated with phosphorus (treatment VIII), and with magnesium (treatment IX). High yields were also supported on treatments with microelements only (treatment X), and on treatments with full dose of physiologically alkaline fertilizers (treatment XVI). Treatments with full doses of mineral fertilizers (treatment VI) caused a reduction in the yield of green mass by about 45 percent, and of dry mass almost by 60 percent (in comparison with crops obtained from plain ash (treatment I). However, the same fertilization supplemented with microelements (treatment V) reduced crops by only 30 percent. Fertilization with potassium did not affect yields. Treatment with sulphur caused an 8-fold decrease in yields.

CONTENT OF SELECTED NUTRIENTS IN WHITE MUSTARD HARVESTED FROM ASH TREATMENTS

Determinations of N, P_2O_5, K_2O, CaO, Na_2O, MgO and S were made on harvested white mustard. The results are presented graphically on fig. 34 and 35 tabulated specifications are provided in interim reports.

Nitrogen

Halemba

White mustard growing on plain ash (treatment III - table 1) contained less nitrogen than plants grown on cultivated soil (treatment I). Addition of macroelements (treatment IV) insignificantly affected the content of N. Doubling the dose of NPK Mg (treatment V) increased the content of nitrogen to 3.6 percent.

Small doses of low bog peat (treatment VII) increased the content of nitrogen in plants as did the addition of sulphur (treatments VIII and XI). Treatments with green mulch (treatments XIII and XIV), treatment with soil (treatment XV), and treatment with gypsum (treatment XVI), produced less nitrogen.

Large doses of high moor peat and green manures (treatments XXII, XXIII and XXIV) caused diminution of crops and a decrease in nitrogen content, which can be explained by an intensive decomposition of organic material in the alkaline ash accompanied by a liberation of toxic compounds.

On ash treatments with low bog peat (treatment XXV) and with mountain peat (treatment XXVI) and with sterile sand (treatment XXVII), the nitrogen contents were similar. While the plants from these treatments contained less nitrogen in comparison with plants from pure ash (treatment III), the crop yields were about three times higher.

Konin

The content of nitrogen in white mustard grown on the various Konin ash treatments varied widely from that measured for the control treatment (treatment I). Relatively large amounts of nitrogen were found in plants growing on plain ash (treatment III). Additions of macro- and microelements to ash from Konin (treatment VI) produced less nitrogen than did unfertilized ash even though the dry mass was higher.

Addition of organic mass in the form of peat variously influenced the nitrogen content. Low bog peat in small doses caused a decrease in the content of nitrogen. The dose of high moor peat (treatment X) as well as larger additions of green mulch (treatments XIII and XIV) increased the content of nitrogen in the crops. High doses of organic fertilizers also increased the nitrogen content of the plants.

The addition of river sand to ash without fertilization (treatment XXVII) produced a lower yield than on plain ash (treatment III), but the plants contained large amounts of nitrogen (4.64 %).

Phosphorus (P_2O_5)

The highest content of phosphorus (1.36 percent) was contained in white mustard growing on mineral soil (treatment I - fig. 34).

The phosphorus content of plants growing on ash from Halemba was less variable than the nitrogen content. In particular ash treatments the plants contained quantities of phosphorus approaching that of plants harvested from pots containing sterile sand (treatment II) and vary from 0.83 to 1.09 percent. This shows that phosphorus in ash was passing into forms less suitable for plants. The highest phosphorus contents occurred in treatments with low bog peat plus sulphur (treatment VII) and in ash treated with large doses of peat (treatment XXI).

Plants cultivated in pots with ash from Konin contained even less phosphorus than the plants cultivated on sterile sand. This probably is related to the high alkalinity of ashes, where phosphorus, in the presence of lime, was transformed to difficult to assimilate forms (e.g., tricalcium phosphorus) the lowest content of phosphorus (0.58 - 0.61 percent) was contained in plants without mineral fertilization. Gypsum and sulphuric acid had relatively small effects on the concentrations of phosphorus (treatments XVI and VII).

Potassium (K_2O)

White mustard harvested from cultivated soil (treatment I) contained 2.09 percent potassium. All other treatments of ash, both from Halemba and Konin, produced while mustard with 2.5 to 3 times more potassium in comparison to treatment I. This indicates large resources of plant available potassium in ash. The white mustard growing on plain ash from Halemba (treatment III) contained 3.64 percent potassium and even Konin ash contained 5.23 percent potassium.

Treatments with green cereal mulch (treatment XXIII) produced the highest potassium content for treatments of ash from Halemba (7.62 percent).

Treatments of ash from Konin which showed the highest potassium content were green manures (treatments XIII and XIV) and soil (treatment XV). The lowest potassium contents were measured in plants raised on the high humidity treatments (treatment XVIII), on treatments with low moor peat (treatments XXV and XXI) and on treatments involving strong compaction of ash (treatment XIX).

Calcium (CaO)

Calcium concentrations in white mustard cultivated on treated ash from Halemba were low indicating small calcium reserves in the subsoil of this macroelement. Main supply source of calcium for the plants were fertilizers. Plants growing on plain ash and on sterile soil contained only a little calcium (treatments II and III).

A definite variation pattern among ash treatments in the content of calcium was not established, as all combinations were collected in the green mass state.

Different concentrations of calcium were correlated with certain treatments of ash from Konin while white mustard in all treatments of ash contained greater quantities of lime in comparison with soil, the most calcium was contained in plants grown on ash (from Konin) without mineral fertilization (treatments III, XXVI and XXVII). The least calcium occurred in plants grown on treatments XIV, VII and XXI.

Sodium (Na_2O)

Plants from treatments with soil (treatment I) contained 5.7 percent sodium compared to only 0.19 percent for plants grown in sterile sand (treatment II). Content of sodium in plants grown on treated ashes varied considerably from 0.20 to 0.83 percent (ash from Halemba), and from 0.56 to 0.94 percent for ash from Konin.

On ash from Halemba the highest amounts of sodium (0.83 and 0.81 percent) were contained in plants grown on ash treated with low moor peat and fertilized with macro- and microelements (treatments XXI and VIII). Lower sodium content is as a rule, connected with lower nitrogen contents.

On ashes from Konin the greatest amounts of sodium were contained in plants harvested from the treatments having a raised humidity level (treatment XVIII). The least amount of sodium was measured in plants growing on plain ash and in ash treated with peat (treatments XXI, XXII, XXV and XXVI).

Magnesium (MgO)

On ashes from Halemba the highest contents of magnesium (above 2 percent) were typical of plants grown on treatments using mineral fertilizers of peat, treatments of pure sulphur, and treatments of green mulch.

Plants grown on Konin ash treatments contained up to three times more magnesium than the plants grown on mineral soil.

Sulphur

Sulphur was measured in plants harvested from selected ash treatments to determine whether additions of sulphur in a form of pure sulphur, of sulphuric acid or as gypsum affected the sulphur content of plants.In all treatments tested the plants contained large amounts of sulphur. The plants apparently obtained enough sulphur from the mineral fertilizers and additional amounts of sulphur did not produce any increase in sulphur content. Contrary to expectations the most sulphur was contained in plants grown on ash fertilized with macro and microelements (treatment VI - Konin), and on ash treated with high moor peat (treatment X - Konin).

CHANGE IN PHYSICO - CHEMICAL CHARACTERISTICS OF ASHES DURING THE GREEN HOUSE EXPERIMENTS

After harvesting the plants, measurement of the ash-soil materials were made to determine whether changes had occurred during the growth period of about 60 days. These laboratory measurements were:
- the grain size distribution
- reaction (pH in H_20 and in KCl)
- chemical composition ($Si0_2$, Fe_20_3, P_20_5, Al_20_3, Ca0, Mg0, K_20, Na_20, S
- content of C and $CaCO_3$
- content of macro- and microelements (P_20_5, K_20, Mg, N, B, Cu, Mn, Mo, Zn)
- content of exchangeable cations and sorptive capacity
- weight and bulk density, general porosity
- capillary and total water capacity
- pF 1.0, 2.0, 2.54, 2.87, 3.0.

Detailed results of analyses were presented in the first interim (progress) report for 1975.

This paper contains a summary analysis of changes in ash properties determined through greenhouse and field tests. (Section No. 8).

SECTION 7

FIELD EXPERIMENTS

PREPARATION OF THE SITE

The field investigations had, as their objectives:

a) The test of protection of the ash surface against wind erosion

b) The test of effectiveness of ash treatments investigated in greenhouse experiments

c) Elaboration of methods of agricultural restoration of the wash

d) Study of methods of agricultural reclamation.

The field experiments on the ash disposal at Halemba were located on surfaces planted in previous years. In 1972, the study area was treated with a mineral fertilizer and sown with a mixture of grasses. In 1973 and 1974 these areas were fertilized with phosporus and nitrogen. A sparse mono-culture of orchard grass (Dactytis glomerata) was thus created. The continued growth of these grasses is dependent on the quantity and the distribution of precipitation and on fertilization. It is believed that after a longer drought or cessation of fertilization, the grasses will die and the surface of ash will again become a source of fugitive dust.

Field experiments on the Konin disposal were set up on an unplanted area as described in Section 5. However, the ash was compacted and required blasting to prepare a plant growth medium. Blasting was conducted from March 17 to April 15, 1975. Blast holes (0.18 m diameter) were drilled on a 1.5 m x 1.5 m grid, to a depth of 1.5 m. Four kg of ammonium nitrate and 1 kg of dynamite were used for each

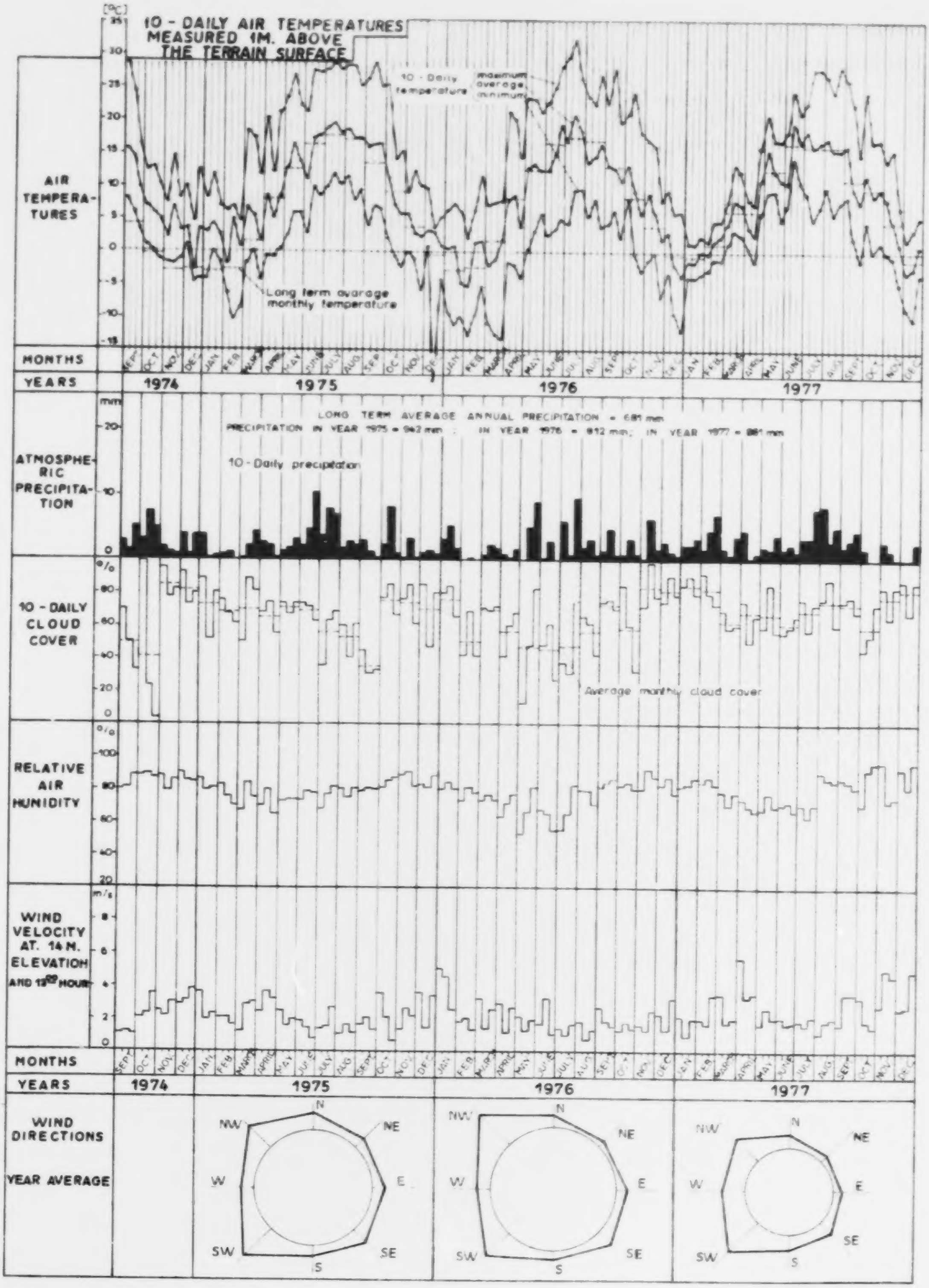


Fig. no. 13. Climatic contitions at the Halemba field plots (1974/77 year).

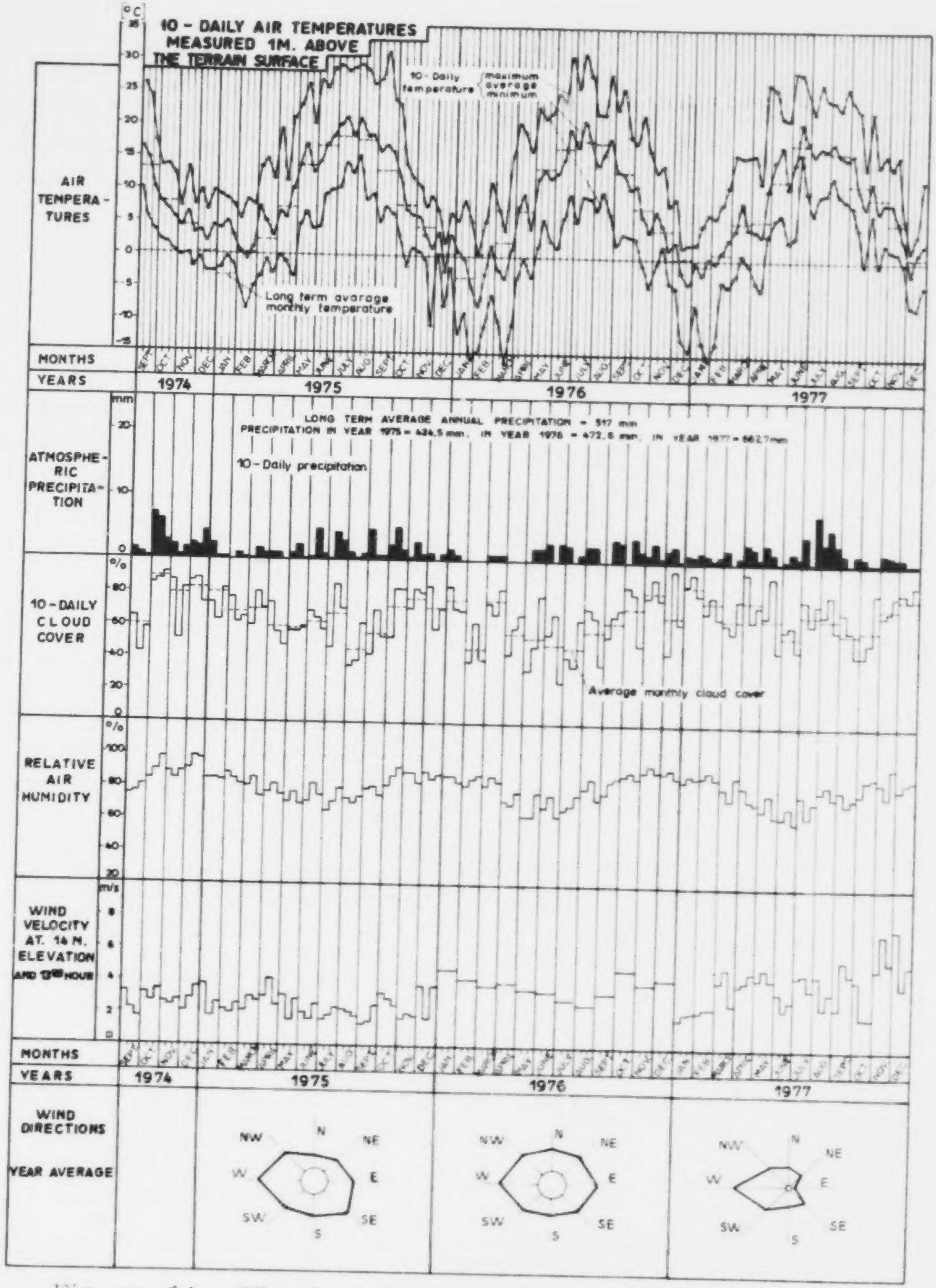


Fig. no. 14. Climatic conditions at the Konin field plots (1974/77 year).

hole, a total of 1434 holes were drilled and 5736 kg of ammonium nitrate and 1434 kg of dynamite were used. The blasting loosened rock to about a depth of 1.5 m in places where the holes were made, and to about 0.6 m between the holes. After blasting, the terrain was levelled with a bulldozer, and then ploughed to depth of 40 cm. In the process the ash rock was crushed into aggregates with sharp edges and diameters up to 50 mm (fig. 6 and 7).

Initial attempts to plough with a specially built, heavy plough and without blasting ended in failure, as the blade of the plow could not penetrate more than 10 cm and slid along wet surfaces created in the process of hydraulic disposal.

The areas of experimental plots on both disposals were fenced to prevent unauthorized access by people or animals.

PREPARATION OF EXPERIMENTS REGARDING AGRICULTURAL RECLAMATION

The field tests of useful vegetation on ash were carried out using the method of independent series with one variable, on 30 cultivated rectangular blocks 6 x 18 m, each with 4 repetitions of the treatment on plots 4 x 5 m (20 m^2 - fig. 15 and 16).

The cultivated area was used to test:

a) Ten different ash treatments designed to change the soil properties of the ash

b) 4 plant crop combinations designed to provide good growth and agricultural benefits.

The number of individual plots with 4 repetitions amounted to 30 x 4 = = 120 plots.

Ash treatments (fig. 15 and 16)

The ten ash treatments consisted of:

A - Covering with fertile soil - 20 cm surface layer (2000 m^3/ha) + + NPK;

SCHEDULE OF STANDARD FERTILIZATION OF ALL FIELD PLOTS
WITH NPK IN THE SPRING OF 1975

Table 14

Timing and placement of fertilization	Type of fertilizer	Dose of fertilizer in kg/ha			
		Halemba		Konin	
		pure component	commercial fertilizer	pure component	commercial fertilizer
1	2	3	4	5	6
a) prior to mixing ash with neutralizing agents	treble superphosphate, 46 % of P_2O_5	140	300	140	300
	ammonium nitrate 34 % of N	35	100	-	-
b) before sowing	treble superphosphate, 46 % of P_2O_5	70	150	140	300
	ammonium nitrate 34 % of N	50	150	50	150
	potash salt 60 % of K_2O	30	50	30	50
c) outside the roots (broadcast)	ammonium nitrate 34 % of N	35	100	35	100
	Total	360	850	410	900

SCHEDULE OF DOUBLE DOSE FERTILIZATION OF PLOTS - N2PK
IN THE SPRING OF 1975

Table 15

Timing and percement of fertilization	Type of fertilizer	Dose of fertilizer in kg/ha			
		Halemba		Konin	
		pure component	commercial fertilizer	pure component	commercial fertilizer
1	2	3	4	5	6
a) prior to mixing ash with neutralizing agents	treble superphosphate, 46 % of P_2O_5	210	450	210	450
	ammonium nitrate, 34 % of N	35	100	-	-
b) before sowing	treble superphosphate, 46 % of P_2O_5	140	300	140	300
	ammonium nitrate 34 % of N	50	150	50	150
	potash salt 60 % of K_2O	30	50	30	50
c) outside the roots (broadcast)	ammonium nitrate 34 % of N	35	100	35	100
	Total	500	1150	465	1050

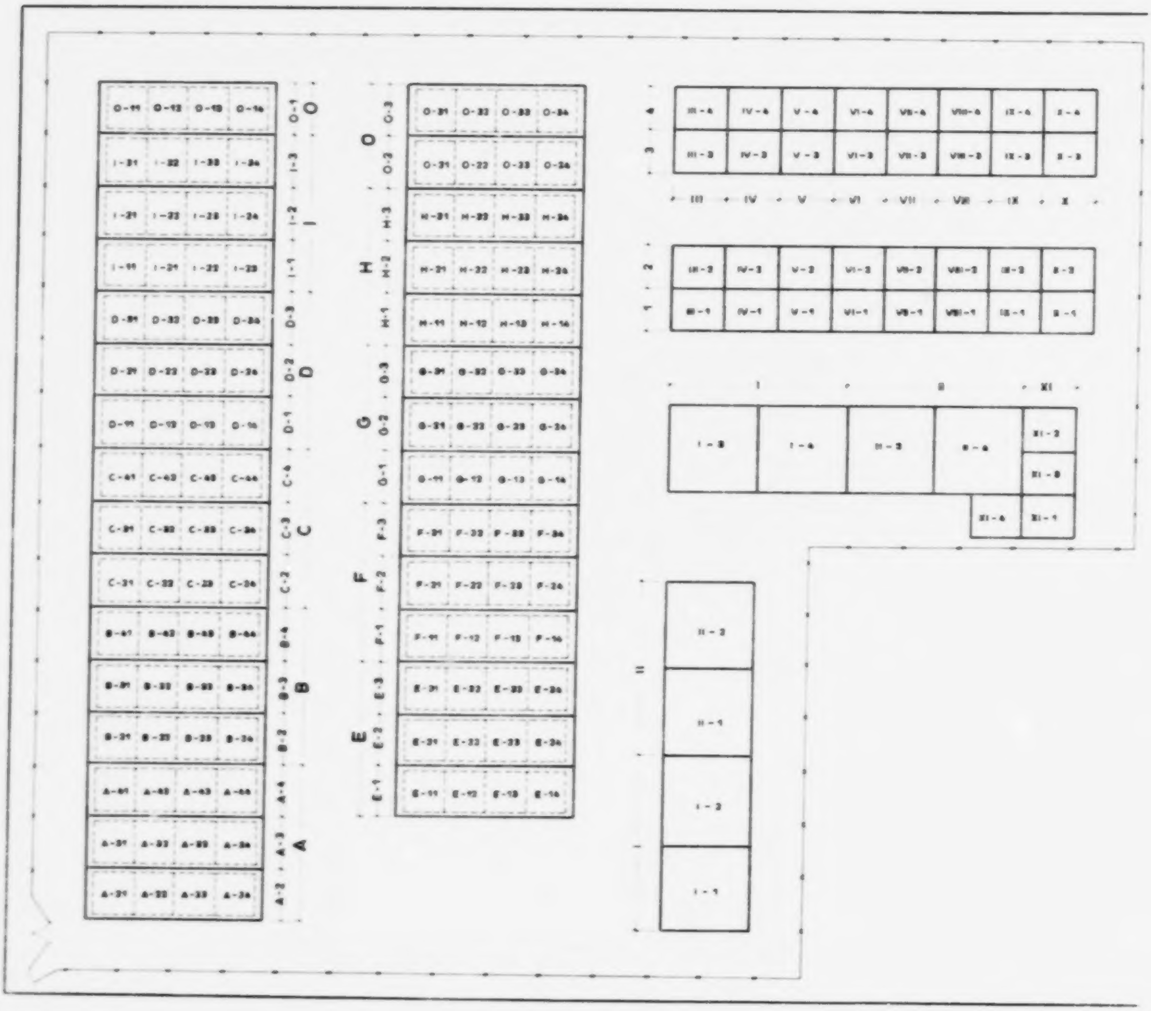

A
B
C
D
I
O
E
F
G
H
III
IV
V
VI
VII
VIII
IX
X
XI
II
I - 1
I - 2
II - 1
II - 2
I - 3
I - 4
II - 3
II - 4
XI - 1
XI - 2
XI - 3
XI - 4

Fig. no. 15. Plan of field plots - Halemba.

AGRICULTURAL RECLAMATION

1 COMBINATIONS

- **A** Covering with fertile soil (20 cm) + NPK
- **B** Covering with fertile soil (10 cm) + NPK
- **C** Covering with fertile soil (5 cm) + NPK
- **D** Covering with bentonite (100 m³/ha) + NPK
- **E** Addition of 10 Mg/ha of low peat + NPK
- **F** Addition of 10 Mg/ha of mountainous peat + NPK
- **G** Addition of 20 Mg/ha of farm manure (in calculation of dry mass) + NPK
- **H** Addition of N_2PK
- **I** Addition of NPK
- **O** Inspection without fertilization (control)

2 MIXTURES OF SEEDS

1 Lucerne

a) lucerne	50 kg/ha
b) white melilot	10 — " —
together	60 kg/ha

2 Grass mixture

a) meadow fescue	12 kg/ha
b) orchard grass	6 — " —
c) smooth bromegrass	12 — " —
d) kentucky bluegrass	5 — " —
e) creeping fescue	11 — " —
f) white clover	3 — " —
g) black medic	[illegible] — " —
h) white melilot	5 — " —
i) darnel	19 — " —
j) redtop	4 — " —
together	80 kg/ha

3 Mixture of legumes

a) lucerne	36 kg/ha
b) orchard grass	6 — " —
or darnel	24 — " —
together	42 or 60 kg/ha

4 White melilot

a) white melilot	50 kg/ha

FOREST RECLAMATION

1 SPECIES OF TREES AND BUSHES

- **I** Poplar I in pits 0.7×0.7×0.7m ; spacing 3×3 m
- **II** Poplar II — " — — " —
- **III** Birch in pits 0.5×0.5×0.5m ; spacing 1×1m
- **IV** Black alder — " — — — " —
- **V** Grey alder — " — — — " —
- **VI** Locust tree — " — — — " —
- **VII** Larch — " — — — " —
- **VIII** Pea shrub 0.3×0.3×0.3m ; spacing 1×1m
- **IX** Willow in pits — " — — — " —
- **X** Willow cuttings ; spacing 0.5 × 1m
- **XI** Poplar cuttings — " —

2 CULTIVATION COMBINATIONS

1 Treatment of pits with fertile soil,

for 1 m³	fly ash	0.75 m³
	fertile soil	0.25 m³
	ammonium nitrate	0.13 kg
	superphosphate	0.30 kg
	potash salt	0.13 kg

2 Treatment of pits with ash + bentonite clay

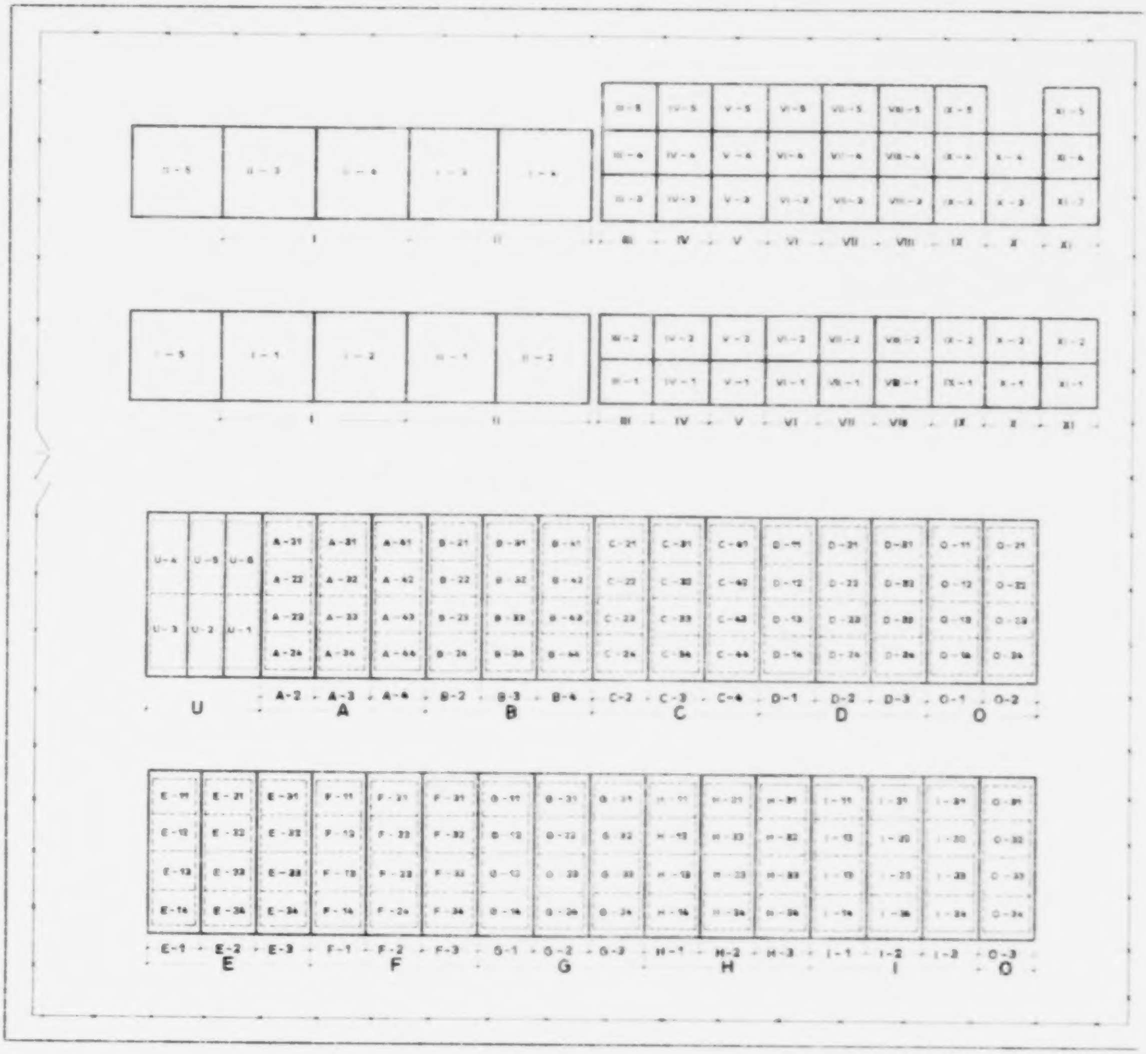
for 1 m³	ash	0.90 m³
	bentonite	0.10 m³
	ammonium nitrate	0.13 kg
	superphosphate	0.30 kg
	potash salt	0.13 kg

3 Treating of pits with peat,

for 1 m³	ash	1.00 m³
	mountain peat	8 kg (16 Mg/ha)
	mineral fertilizers as in pos 1	

4 Filling up of ditches with mixture + NPK

for 1 m³	ash	1.00 m³
	mineral fertilizers as in pos 1	



I
II
III
IV
V
VI
VII
VIII
IX
X
XI
A-2
A-3
A-4
B-2
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B-4
C-2
C-3
C-4
D-1
D-2
D-3
O-1
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U
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H-1
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H-3
I-1
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O-3
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F
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H
I
O

Fig. no. 16. Plan of field plots - Konin.

AGRICULTURAL RECLAMATION

1. COMBINATIONS

- **A** Covering with fertile soil (20 cm) + PK
- **B** Covering with fertile soil (10 cm) + PK
- **C** Covering with fertile soil (5 cm) + PK
- **D** Covering with tertiary sand 500 m^3/ha + PK
- **E** Addition of 10 Mg/ha of low peat + PK
- **F** Addition of 10 Mg/ha of montainous peat + PK
- **G** Addition of 20 Mg/ha of farm manure (in calculation of dry mass) + PK
- **H** Addition of 40 Mg/ha of green fertilizer (maize) + PK
- **I** Addition of PK
- **O** Inspection without fertilization (control)

2. MIXTURES OF SEEDS (1976 year)

1 Sainfoin

a) sainfoin in a pure state	280 kg/ha

2 Grass mixture

a) meadow fescue	24 kg/ha
b) orchard grass	8 —"—
c) smooth bromegrass	24 —"—
d) kentucky bluegrass	10 —"—
e) creeping fescue	34 —"—
f) white clover	6 —"—
g) black medic	14 —"—
h) white melilot	6 —"—
i) darnel	26 —"—
j) redtop	8 —"—
together	160 kg/ha

3 Mixture of legumes

a) lucerne	72 kg/ha
b) orchard grass	12 —"—
together	84 kg/ha

4 White melilot

a) White melilot in a pure state	100 kg/ha

FOREST RECLAMATION

1. SPECIES OF TREES AND BUSHES

- **I** Poplar I - in pits 0.7×0.7×0.7 m - spacing 3×3 m
- **II** Poplar II - —"— —"—
- **III** Birch - in pits 0.5×0.5×0.5 m - spacing 1×1 m
- **IV** Grey alder - —"— - —"—
- **V** Black alder - —"— - —"—
- **VI** Locust tree - —"— - —"—
- **VII** Willow - —"— - —"—
- **VIII** Sea buckthorn - in pits 0.3×0.3×0.3 m - spacing 1×1 m
- **IX** Pea shrub - —"— —"—
- **X** Poplar cuttings - spacing 0.5×1 m
- **XI** Larch - in pits 0.5×0.5×0.5 m - spacing 1×1 m

2. CULTIVATION COMBINATIONS

1 Treatment of pits with fertile soil + ash + PK, for 1 m^3

ash	0.75 m^3
fertile soil	0.25 m^3
ammonium phosphate	0.30 kg
urea	0.13 kg

2 Treatment of pits with ash + tertiary sand + PK, for 1 m^3

ash	0.75 m^3
tertiary sand	0.25 m^3
mineral fertilizers as in pos 1	

3 Treating of pits with low peat + PK for 1 m^3

ash	1.00 m^3
low peat (dry mass)	15 kg
mineral fertilizers as in pos 1	

4 Filling up of ditches with mixture + PK; for 1 m^3

ash	1.00 m^3
mineral fertilizers as in pos 1	

5 Treatment of pits with fertile soil + PK, for 1 m^3

fertile soil	1.00 m^3
ammonium phosphate	0.30 kg
urea	0.13 kg
potash salt	0.13 kg

B - Covering with fertile soil - 10 cm surface layer (1000 m^3/ha) plus NPK;

C - Covering with fertile soil - 5 cm surface layer (500 m^3/ha) plus NPK;

D - Covering surface with 5 cm layer of tertiary sand (500 m^3/ha), (only on disposal in Konin), or with 1 cm layer of bentonite and NPK 100 m^3/ha (only disposal in Halemba)

E - Mixing of low moor peat (10 t/ha dry mass) i.e. 30 m^3/ha of air dried peat, plus NPK

F - Mixing of gardening mountain peat (10 t/ha dry mass plus NPK)

G - Farm manure (20 t/ha) plus NPK

H - Mineral fertilization with double dose of phosphoric fertilizers (N2PK)

I - Standard mineral fertilizers (NPK) in quantities given in table 14

0 - Control.

The types and amounts of ash treatments were determined from the greenhouse experiments previously described. Green mass was not available during the time of setting up the experimental plots (spring time), therefore farm manure was used as a substitute. Due to the lack of vegetation on H series plots at Konin, the plot treatment of H series plots was modified with the additional treatment of chopped maize at a rate of 40 t/ha mixed in with a deep plow. Plots of this series were then redesignated by the letter K.

The "fertile soil" used on plots A, B and C was:

- at Halemba a humus soil from meadow areas including shallow peats (organic-rich materials);
- at Konin organic layers of agricultural soils formed from clayey sands of glacial origin.

The tertiary sand used at Konin was obtained from the overburden of lignite mine; there the sand contains lignite which does reduce the pH of the material.

DUST FALL ON EXPERIMENTAL FIELDS

Table 16

Period (month)	Dust fall in t/km^2/month					
	H a l e m b a			K o n i n		
	1975	1976	1977	1975	1976	1977
1	2	3	4	5	6	7
January	.	20.3	30.2	.	18.6	5.6
February	.	20.3	19.3	12.9	23.8	50.3
March	.	19.8	18.4	14.3	27.4	45.3
April	.	29.1	14.8	26.8	15.8	16.2
May	.	20.3	19.5	27.7	113.7	34.7
June	14.2	26.0	15.1	20.6	30.9	58.1
July	21.8	22.5	17.3	15.7	22.4	58.3
August	12.6	14.5	17.4	15.6	21.0	
September	12.6	14.5	18.0	14.6	30.8	30.0
October	14.9	14.9	17.5	10.4	34.6	7.4
November	14.9	20.8	14.9	10.4	60.9	15.3
December	15.1	18.5	14.4	18.1	14.3	20.2
Total	106.1	241.5	216.8	187.1	414.2	361.6

Bentonite, used at Halemba was obtained from the bituminous coal mines there. Its main component is montmorillonite, which has a high sorption capacity, which could improve the water holding capacity of porous materials.

The peat used at the two sites was:

- at Halemba a thin layer of woody peat produced in the valley of Czarna Przemsza river
- at Konin thin layers of woody sedge peat formed in the valley of Struga Biskupia creek.

These peats are characterized by significant mineralization. Peats from the valley of Czarna Przemsza appear to be strongly contaminated with zinc compounds, which are likely produced by effluents from zinc smelters located in the region.

The high moor mountain peat was garden peat produced from sphagnum mosses. It is slightly decomposed and acid. Standard NPK fertilization amounts to the amounts described in table 14 and double fertilization 2NPK - according to table 15.

Seed mixture (fig. 15 and 16)

Four general seed mixtures were used in the field trials, with modification in the case of one mix for the differences of the two sites. The mixtures were as follows.

Seed mix 1:

		Seeding rate
a) Halemba:		
- alfalfa (Medicago Sativa)	-	50 kg/ha
- white melilot (Melilotus albus)	-	10 kg/ha
	Total	60 kg/ha
b) Konin:		
- sainfoin (Onobrychis viciaefolia)	-	140 kg/ha
- crown vetch (Coronilla varia)	-	70 kg/ha
	Total	210 kg/ha

CONCENTRATIONS OF SO_2 AND F IN THE VICINITY OF VEGETATION EXPERIMENTS

(20 min, collection period)

Table 17

Month	Halemba									Konin								
	1975			1976			1977			1975			1976			1977		
	Measurement date	20-min, concentration in mg/m^3		Measurement date	20 min, concentration in mg/m^3		Measurement date	20-min, concentration in mg/m^3		Measurement date	20-min, concentration in mg/m^3		Measurement date	20-min, concentration in mg/m^3		Measurement date	20-min, concentration in mg/m^3	
		SO_2	F_2		SO_2	F_2		SO_2	F_2		SO_2	F_2		SO_2	F_2		SO_2	F_2
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
January	. x/	.	.	9	0,80	0,103	7	0,6	0,2	.	.	.	26	0,1000	traces	24	0,0217	0,0922
February	.	.	.	9	0,70	0,103	7	0,7	0,1	.	.	.	4	0,0925	"	28	0,0273	0,0739
March	.	.	.	9	0,75	0,096	7	0,9	0,1	.	.	.	5	0,1100	"	22	0,0345	0,0900
April	.	.	.	9	0,85	0,098	7	0,7	0,1	.	.	.	5	0,0104	0,025	27	0,0165	traces
May	.	.	.	10	0,70	0,085	6	0,7	0,1	14	0,03	traces	3	0,33	0,025	27	0,0179	"
June	4	0,4	0,084	9	0,95	0,145	7	0,4	0,1	26	0,015	0,0125	21	0,261	0,125	30	0,0184	"
July	7	2,9	0,056	10	0,66	0,090	7	0,8	0,1	23	0,31	traces	30	0,0054	traces	28	0,0300	"
August	12	0,7	0,085	10	0,63	0,090	8	0,7	0,1	7	0,55	0,025	30	0,1096	0,0275	31	0,0202	"
September	12	0,8	0,085	10	0,63	0,090	8	0,7	0,1	3	0,049	traces	27	0,0675	0,0275	28	0,0216	"
October	13	0,9	0,090	11	0,62	0,125	7	0,9	0,1	2	0,08[illegible]	"	28	0,0117	0,0260	27	0,0460	"
November	10	1,06	0,095	10	0,67	0,095	7	1,1	0,1	28	0,0025	0,050	29	0,0244	0,0899	25	0,0661	"
December	2	0,98	0,125	10	0,62	0,103	7	1,0	0,1	10	0,01	0,025	23	0,0512	0,0383	21	0,0432	"
Max.		2,9	0,125		0,95	0,145		1,1	0,1		0,55	0,050		0,33	0,125		0,0661	0,0922

x/ Observations began June 1975

Seed mix 2:

Grass mixture:

- meadow fescue (Festuca pratensis)	-	12 kg/ha
- orchard grass (Dactylis glomerata)	-	4 kg/ha
- smooth bromegrass (Bromus inermis)	-	12 kg/ha
- meadow grass (Poa pratensis)	-	5 kg/ha
- creeping fescue (Festuca rubra)	-	17 kg/ha
- white clover (Frifolium repens)	-	3 kg/ha
- alfalfa (Medicago Lupulina)	-	7 kg/ha
- white melilot (Melilotus albus)	-	5 kg/ha
- tall rye-grass (Arrhenatherum elatius)	-	13 kg/ha
- bent grass (Agrostis stolonifera)	-	4 kg/ha
total		82 kg/ha

Seed mix 3:

- lucerne (Medicago sativa)	-	36 kg/ha
- orchard grass (Dactilis glomerata)	-	6 kg/ha
total		42 kg/ha

Seed mix 4:

- white melilot (Melilotus albus)	-	50 kg/ha.

Seed bed preparation

The amendments and initial portions of fertilizers were rototilled to a depth of 20 cm into the ash prior to seeding. After 6-10 days the second addition of mineral fertilizers was raked in. A few days later the various seed mixtures (described above) were broadcast, raked in, and rolled with a smooth roller.

PREPARATION OF EXPERIMENTS USING TREES AND SHRUBS

The surface of field plots used to test forest-type reclamation were prepared according to the type of trees and shrubs planted.
The area for forest-type reclamation was divided into:

a) 10 combinations of trees and shrubs

b) 4 ash treatments dependent on the method of ash preparation.

Planting combinations (fig. 15 and 16)

a) Halemba

I - poplar robusta I (Populus robusta Schn.)
II - poplar robusta II (Populus robusta Schn.)
III - white birch (Betula verrucosa Ehrh.)
IV - black alder (Alnus glutinosa Gaertn.)
V - grey alder (Alnus incana Moench.)
VI - locust tree (Robinia pseudoacaccia L.)
VII - European larch (Larix decidua Mill.)
VIII - pea shrub (Caragana arborescens Lam.)
IX - gray willow cross with basket willow (Salix cinerea L. S. viminalis L.)

X - willow cuttings - Russel willow (Salix cross with rousseliana Willd = Salix alba cross with Salix fragilis)

b) Konin

I - Simon poplar (Populus simonii Carr.)
II - poplar robusta (Populus robusta Schn.)
III - white birch (Betula verrucosa Ehrh.)
IV - grey alder (Alnus incana Moench.)
V - black alder (Alnus glutinosa Gaertn.)
VI - locust tree (Robinia pseudoacaccia L.)
VII - sharpleaf willow (Salix acutifolia Willd.)
VIII - sea buckthorn (Hippophae rhamnoides L.)
IX - pea shrub (Caragana arborescens Lam.)
X - cuttings of late poplar (Populus cross with serotina Hart.).

Ash treatments (fig. 15 and 16)

1. Treatment of ash pits (dug in disposal area) with soil and fertilizers in the following proportions (per/m^3):

- ash	- 0.75 m^3
- fertile soil	- 0.25 m^3
- ammonium nitrate, 34 % N	- 0.13 kg
- superphosphate, 46 % P_2O_5	- 0.30 kg.

2. Treatment of ash pits with mineral fertilizers and tertiary sand (Konin) or bentonite (Halemba) in the following proportions (per 1 m^3):

	Konin	Halemba
- ash	0.75 m^3	0.90 m^3
- tertiary sand (Konin) bentonite (Halemba)	0.25 m^3	0.10 m^3
- ammonium nitrate, 34 % N	0.13 kg	0.13 kg
- superphosphate, 46 % P_2O_5	0.30 kg	0.30 kg.

3. Treatment of ash with mountain peat plus NP in the following proportions (per 1 m^3):

- ash	- 1.00 m^3
- mountain peat	- 8 kg (dry mass)
- ammonium nitrate	- 0.13 kg
- superphosphate	- 0.30 kg.

4. Treatment of ash with mineral fertilizers in the following proportions (per 1 m^3):

- ammonium nitrate 34 % N	- 0.13 kg
- superphosphate 46 % P_2O_5	- 0.30 kg

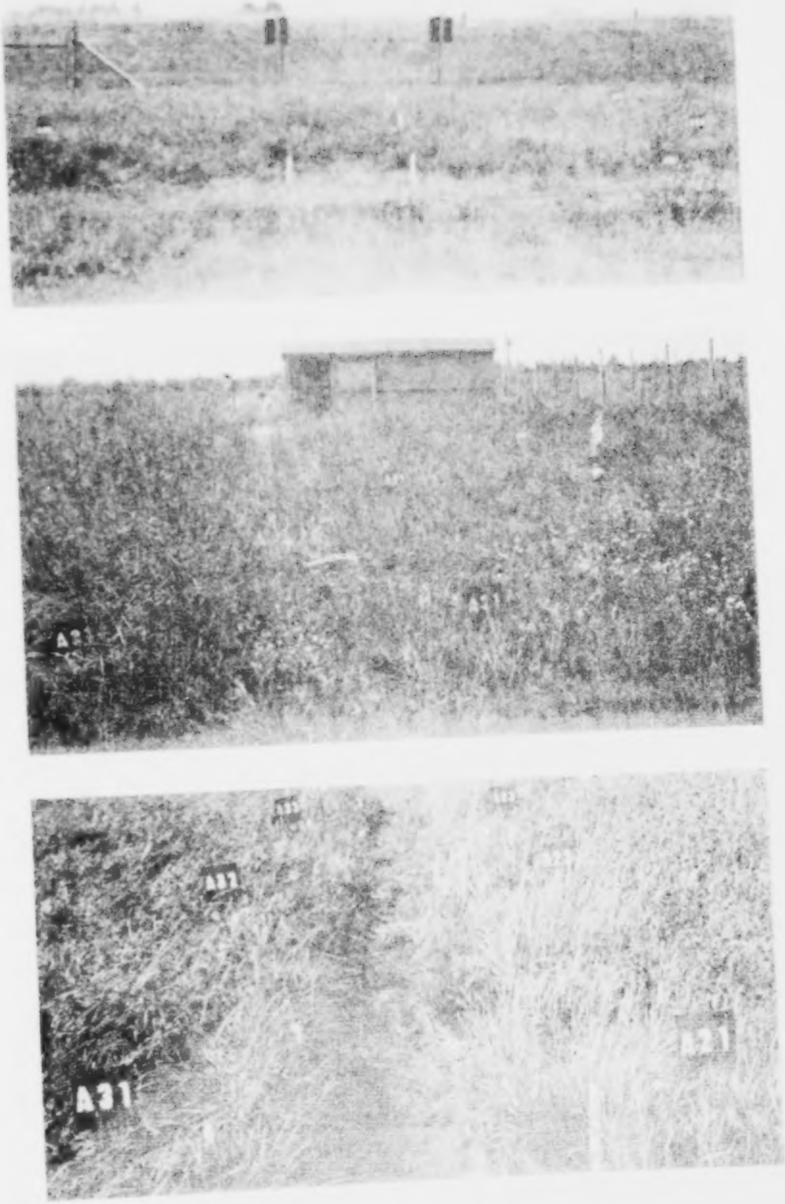

year I
year II
A31
year III
A31
A21

Fig. 17. Field experiments in Halemba – cultivation of grasses (A-2) and (A-3) mixtures in the I, II and III year of growth (plots covered with 20 cm layer of fertile soil + NP).

Plot preparation and planting (fig. 15 and 16)

At Konin the ash was crushed as described above and deeply tilled to a depth of 0.40 m. At Halemba grass was removed from the vicinity of the plots.

The trees and shrubs were planted using the following spacing:

- poplars - 3.0 x 3.0 m
- other types of trees - 1.0 x 1.0 m
- poplar combined with willow cuttings - 1.0 x 1.0 m

The sizes of the pits dug in the ash were:

- poplars - 0.7 x 0.7 x 0.7 m = 0.347 m^3
- other types of trees - 0.5 x 0.5 x 0.5 m = 0.125 m^3
- bushes - 0.3 x 0.3 x 0.3 m = 0.027 m^3.

The pits were backfilled with ash and amendments described above. The trees and bushes were irrigated once after planting with 10 dm^3 for poplars and 5 dm^3 for all other species.

The plots for poplar and willow cuttings were treated with four variants as follows:

1) A top dressing of fertile soil (20 cm layer), plus NPK as on grass test plots designated series "A".

2) A top dressing of either tertiary sand (Konin), or bentonite (Halemba) plus NPK, as on grass test plots of designated series "D".

3) Treatment with mountain peat and fertilizers, as on grass test plots designated series "F".

4) Treatment with fertilizers as on grass test plots designated series "I".

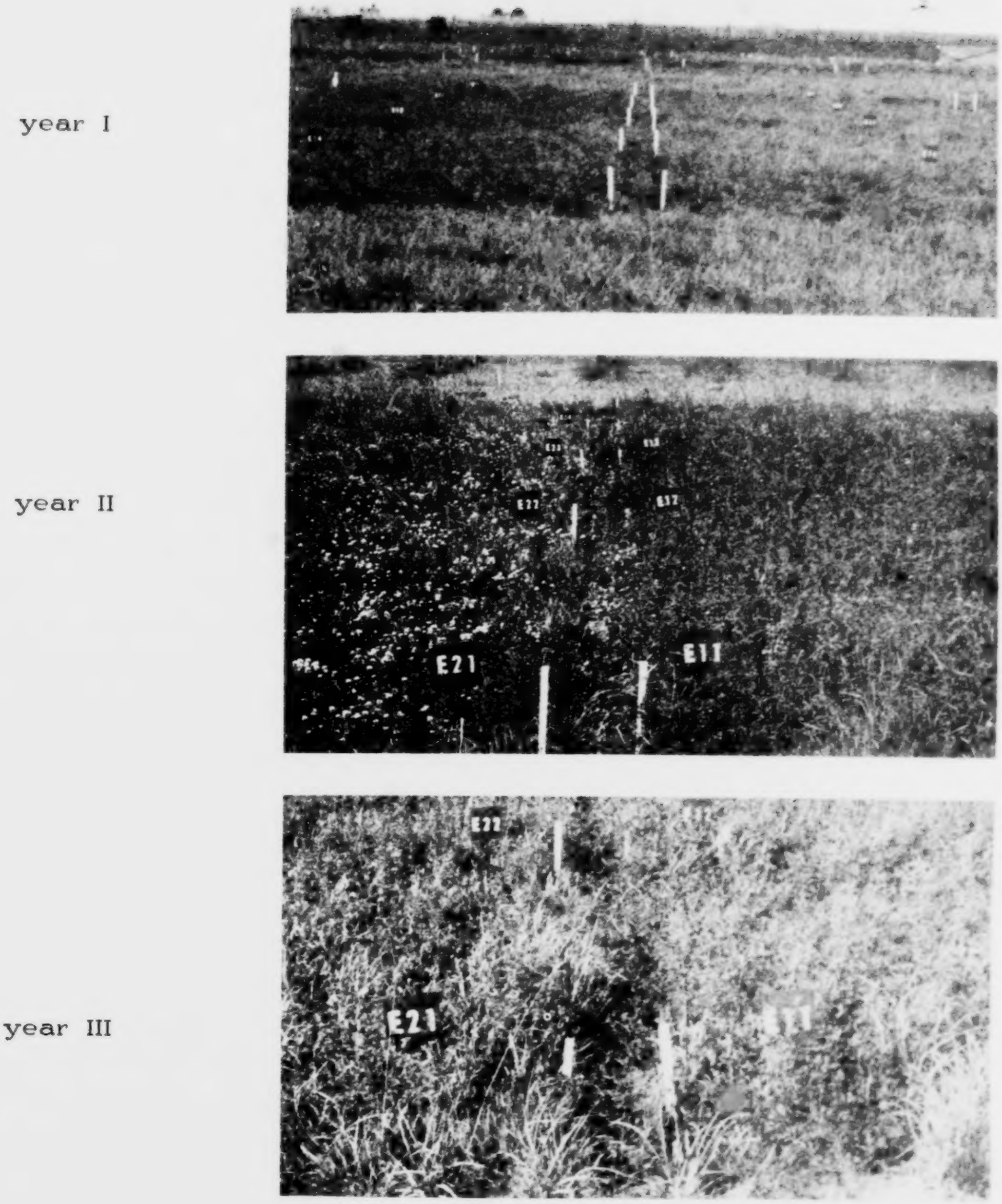

year I
year II
E22
E12
E21
E11
year III
E22
E21
E11

Fig. no. 18. Field experiments in Halemba - cultivation of lucerne (E-1) and grass mixtures (E-2) in the I, II and III year of growth (plots treated with low moor peat + NP).

CONSOLIDATION OF SURFACE

To counteract wind erosion of the ash surface of experimental area (until the time when the vegetation provides adequate stabilization), it was temporarily stabilized with a latex emulsion applied to the surface.

The ash disposal area at Konin was first disk harrowed in the areas surrounding the plots. These areas were then fertilized and seeded with a mixture of grasses and nitrogen-forming plants (forbs). These surfaces were then covered - together with the expriment plots - with the solution of latex. The fertilizers applied prior to seeding were:

- 150 kg/ha of superphosphate, containing 46 % P_2O_5
- 150 kg/ha of ammonium nitrate containing 34 % N.

The grass-forb mixture was that described above as "seed mix 2". On 11 Jun. 75 the whole area of the Konin experimental field was covered with water solution of latex LBSK-5545, supplied by Chemical Works "Oświęcim" in Oświęcim. The water solution was obtained by diluting 1200 dm^3 of latex with 12 000 dm^3 of water (volume ratio 1:10). The solution was distributed using fire fighting. apparatus mounted on a tank truck. Distribution of latex amounted to 833 dm^3/ha, which created a layer roughly 0,08 mm thick (fig. 23).
On 12 Jun. 75 the surface layers of the ash (3 to 6 mm) on the experimental plots was observed. The land between the plots which had been harrowed and seeded did not show any visible hardening of the near surface layers.

A similar surface hardening was observed on the experimental plots at Halemba. The latex application at Halemba was the same as at Konin. The land surrounding the plots was already covered with grass from previous experiments.

THE WEATHER DURING THE FIELD EXPERIMENTS

Halemba

Precipitation measurements were conducted at a location about 5 km from the experimental field. All other climatic data were measured in climatic station Ciekanów, 10 km away. The results of observations for the period November 1974 through October 1977 are presented on fig. 13.

The winter of 1974/75 was characterized with air temperatures higher than the long term average, which was related to prevailing south - westerly winds, that generally carry warm and moist air. May was particularly warm and this was conducive to vegetative growth of grasses. In the autumn (October 1975) the temperature fell to below the long term average and heavy precipitation occurred. Low temperatures were maintained during winter and in to the early spring of 1976. The summer of 1976 was normal. During the second half of October 1976 the temperature again dropped (to - 3.0°C). The winter of 1976/77 had average temperatures. Temperatures increased in the late spring of 1977 (to 17.7°C on Mar. 23 and 25, and 27.2°C on Apr.30) but then suddenly dropped (to 0.7°C on the June 1), the effect of which was a freezing of all the young shoots of the trees, especially of the locust and alder. Subsequent rises in temperatures accompanied by high rainfall positively influenced the first cutting of hay in June 1977.

The average annual precipitation is 681 mm for the Halemba region. 1975 was an exceptionally wet year since the measured precipitation was 942 mm. After a relatively high precipitation (snow and sleet) in the winter of 1975/1976, the spring season was average. In June and July storms occurred. In May, low precipitation was combined with high temperatures, low humidity of air, little overcast, and strong winds. Such conditions contributed to many failures of trees and shrubs planted in April and May. During the 1976/77 winter snow falls with moderately low temperatures permitted accumulation of moisture which was utilized year I

year II

year III

Fig. no. 19a,b,c. Field experiments in Halemba -cultivation of mixtures of grasses (0-2) and (0-3) on ash in the I, II and III year of growth (in the III-rd year N and P fertilization) - control.

in the spring. In 1976 precipitation (812 mm) was clearly smaller than in 1975, but its distribution was better for plant growth. In May the precipitation was two times greater than average. Thus the spring of 1976/77 helped to further supplement the soil humidity. This and periodical spring rains in 1977 gave good yields for the first harvest of grasses.

Konin

Climatic measurements were performed at a station 1 km from the experimental field. The results of observations are presented on fig. 14.

In contrast to Halemba, the climatic conditions here were not favourable for the field experiments. The winter of 1974/75 was characterized with higher temperatures than average, January was particularly warm (average + 4.0°C in comparison to the long term average of 2.8°C). Spring and summer temperatures were also higher than average. These temperatures were accompanied by low rainfall which caused excessive drying of the soil and adverse effects on germination and growth of plants. The autumn months of 1975 were exceptionally cold (November temperatures were lower than in the winter of 1975/76). Moreover, the low temperatures persisted to the end of March 1976. Temperatures during the remaing part of the year were average. The winter of 1976/1977 was also long and cold. The spring of 1977 had alternating warm and cold spells as also occurred in Halemba. The spring of 1977 was average in comparison to longer term trends, but was more advantageous for growth of vegetation than the preceding years.

The long term average annual precipitation for the Konin region is 517 mm. In 1975 the precipitation was only 434.5 mm. The period from February to mid June was dry since precipitation constituted merely 40 percent of average precipitation for that period (89.6 mm, instead of 187.3 mm).

In Poland the snow fall from November through February has agreat influence on vegetation, as do the spring rains from March

year I
year II
A-24
A-34
year III
A-22
A-32

Fig. no. 20. Field experiments in Konin - cultivation of mixtures of grasses (0-2) and (A-3) on I, II and III year of growth.

through June. At Konin during 1975 the precipitation in the form of snow during this period amounted to only 50 mm. Thus soil moisture was quite low. Increased precipitation in the autumn of 1975 caused partial regeneration of the soil moisture. 1976 was an exceptionally dry year, since from February to mid June only 76.0 mm of precipitation was measured (in comparison to the long term average of 187.3 mm). Not until autumn did more normal precipitation occur. Precipitation during the winter of 1976/77 and during 1977 was closer to normal and higher growth of vegetation on the test plots was observed.

AIR QUALITY NEAR ASH TREATMENT AREAS (tables 16 and 17)

Measurements of air quality in the vicinity of the ash experiment areas involved: (1) dust fall, (2) SO_2 concentration, and (3) F_2 concentration.

The results of these measurements are presented in tables 16 and 17 dust fall was measured by weighing the dust collected in vessels suspended over the test areas. The vessels were exposed between the measurement dates shown in the tables.

Sulphur dioxide concentrations were measured by absorption in a 5 % solution of potassium chlorate.

Fluoride concentrations were measured using sodium hydroxide titration with thorium nitrate against alizarin indicator (at a pH of 2.9).

These measurements indicate that significant air pollution exists in the areas of the experiments. Thus there is a high potential to adversely affect biochemical processes. This has to be considered in the assessment of results of field tests.

THE COURSE OF THE FIELD EXPERIMENTS OF PERFORMED AGRICULTURAL RECLAMATION IN YEARS 1975 - 77

Halemba

Relatively good germination occurred on the experimental treatment plots at Halemba during the spring of 1975. However, there were variations in germination and growth between various treatments.

In August of 1975 all the plots were fertilized (with the exception of "0" series) with ammonium nitrate at a rate of 50 kg/ha, (20 kg/ha of nitrogen). This same dose was applied to the land occurring between the test plots.

On the 29-th of September 1975 the plants on all plots were cut and samples collected for drying and for laboratory analysis.

After significant frosts and sparse snow cover freezing of many plants was observed especially alfalfa (Medicago sativa). This phenomenon is often observed in Poland and often results in the death of the plant. In the experimental plots the frozen plants were not abandoned, but rather in the spring of 1976 the area was refertilized and harrowed. These applications of fertilizers on all plots amounted to:

- 60 kg/ha of P_2O_5, (400 kg/ha of fertilizer in a form of 18 % superphosphate)
- 50 kg/ha of N (110 kg/ha of 46 % (N) urea).

The initial plant response was not ideal at Halemba as a result of freezing and drought, and it was also decided to reseed the plots. All plots were reseeded with:

a) alfalfa (Medicago sativa) at a rate of 70 kg/ha and
b) orchard grass (Dactilis glomerata) at a rate of 12 kg/ha.

In June of 1976 the plants were mown again and samples taken for laboratory analyses (chemical composition, protein content). Immediately after mowing mineral fertilizers were again applied at the following rates:

- 50 kg/ha of P_2O_5 in the form of granulated treble superphosphate (46 % P_2O_5)
- 50 kg/ha of N (110 kg/ha of 46 % (N) urea).

By the end of June of 1976 after harrowing and reseeding the plots of treatment series A through D had developed a much more dense stand of vegetation. Effects of the freezing and drought appeared to have been alleviated. Treatment series E through H and O were adversely affected to a high degree by the freezing and dry weather, and vegetation remained stressed even after reseeding. While rains on the 6th and 12th of July finally provided needed moisture, at the end of the growing season the development of plants remained unsatisfactory, and was reflected in the measured yields. In fact, the yields were satisfactory only on treatment plots of A and B series, and on some treatment - vegetation combinations of the E and H series.

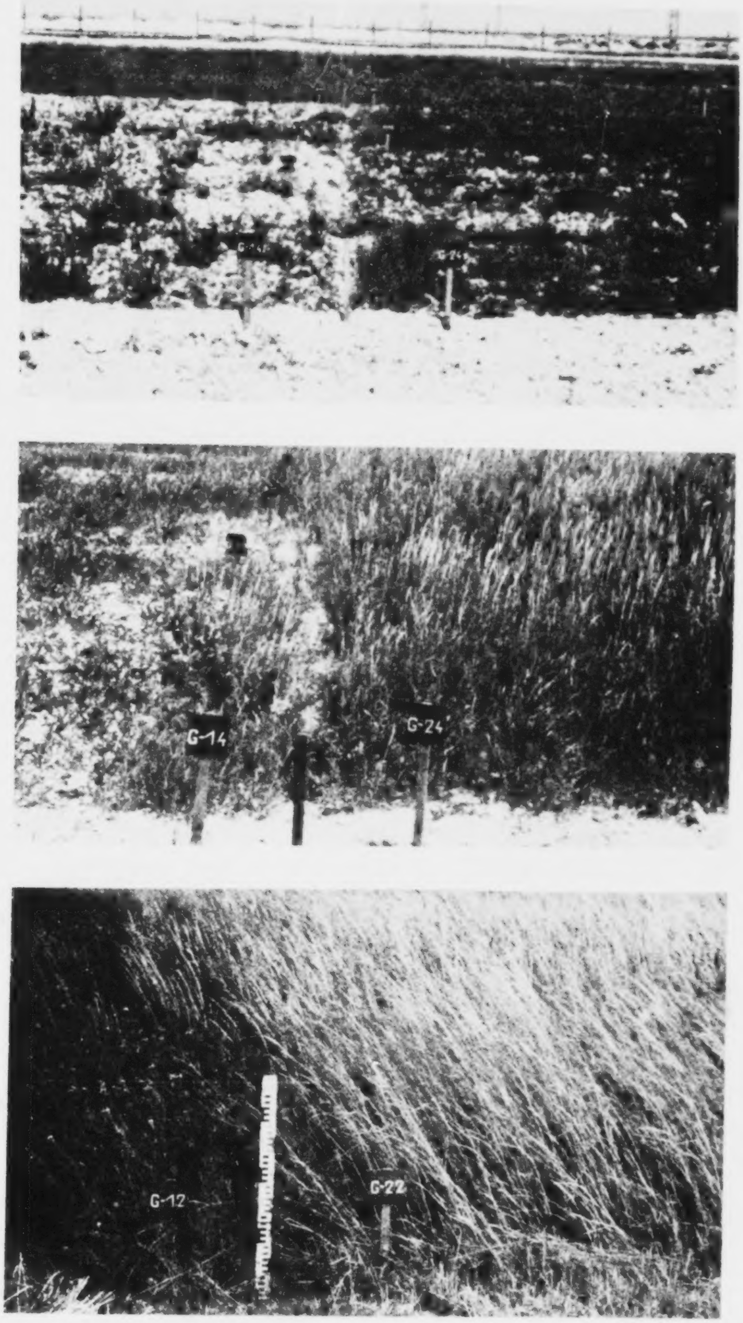
The plants were mown on 30 Aug. 76 and the plots subsequently fertilized with nitrogen at a rate of 50 kg/ha (110 kg of 46 % urea). Some plant growth continued until winter and permitted a third harvest.

In response to the expressed wish of Project Officer during the 1977 growing season mineral fertilization was applied to only two repetitions of each series from A through I (e.g. repetitions A-21 and A-22). The remaining two other repetitions remained without fertilization and without cultivating treatments (e.g. repetitions A-23 and A-24).

In the spring of 1977 fertilizers were applied only to the above described repetitions (nos 1 and 2) at the rates:

- 60 kg/ha of P_2O_5, (130 kg/ha of treble superphosphate)
- 100 kg/ha of N, (220 kg/ha of 46 % urea).

The plots were harrowed after fertilization. The first cutting was collected on 30 May 77, and the treatment plots were refertilized at the same rate used in the spring and described above. The second haruest was gathered Sept. 8, 1977. An increasing difference was observed in crops from fertilized and from not fertilized plots.



year I

year II

year III

Fig. no. 21. Field experiments in Konin - cultivation of sainfoin with crown vetch (G-1) and mixtures of grasses (G-2) on ash with addition of farm manure + NP in the I, II and III year of growth.

The acquired results, characterizing suitability of treatments performed in the course of reclamation, are presented in later part of this report. During the 3 years of field experiments, the changes in the character of the soil medium were measured. Results of these investigations are discussed in a later part of this report. (Section 8 and 9).

Konin

The experimental treatment plots at Konin showed relatively good growth in the spring of 1975 only on plots of A, B and C series (plots treated with soil) however, unsatisfactory results were obtained on those plots where white melilot (Melilotus albus) was seeded. None of the crown vetch germinated. The germination of sainfoin (Onobrychis viciaefolia) was completely unsatisfactory. The best germination occurred with orchard grass (Dactylis glomerata) and (Medicago sativa). Poor germination can be ascribed mainly to adverse weather conditions (shortage of precipitation and high temperatures), and to significant salinization of the soil. Furthermore, mixtures of grasses and nitrogen-producing plants are not always productive in the first year growth in Poland.

In order to counteract the poor growth of grasses and nitrogen-forming plants at Konin, all plots except those of the "0" series were fertilized on the 28 Aug. 75 at the rates:

a) 24 kg/ha of N (50 kg/ha of 46 % (N) urea).

b) 90 kg/ha of P_2O_2 and 35 kg/ha of N in the form of ammonium phosphate (18 % N and 46 % P_2O_2 at 200 kg/ha).

Despite sufficient precipitation during the second half of 1975 little improvement in vegetative growth occurred and therefore the vegetation was not cut in 1975. In autumn months of 1975 numerous colonies of very primitive cyanoses (Chroococcales) appeared on the test plots. These colonies usually grow (in Poland) on wet limestones or on masonry. They play a role in the first colonizing of plants on rocks.

On three treatment combinations in the H series (H-1, H-2 and H-3) and in all four repetitions - where vegetation wholly vanished - the plots were further treated with 40 t/ha of "green manure" (cut maize). These plots were also fertilized at the following rates:

a) 90 kg/ha N and 230 kg/ha P_2O_5 (500 kg/ha of ammonium phosphate with 18 % N and 46 % P_2O_5)

b) 90 kg/ha N (200 kg/ha of urea with 46 % N).

The maize and fertilizer was tilled in and left in straight furrows for the winter.

In the spring of 1975 on all treatments the plots were cultivated, fertilized and reseeded to varying extents. These additional treatments were applied as follows:

a) Fertilization

1) 60 kg/ha of P_2O_5 in the form of triple granulated superphosphate (130 kg/ha of industrial fertilizer) was applied to all plots but those of the "0" series.

2) 50 kg of N in the form of urea (110 kg/ha of fertilizer) was applied to all plots after germination (except those of the "0" series).

b) Cultivation

1) All plots were harrowed after snow had melted and the surfaces had dried out

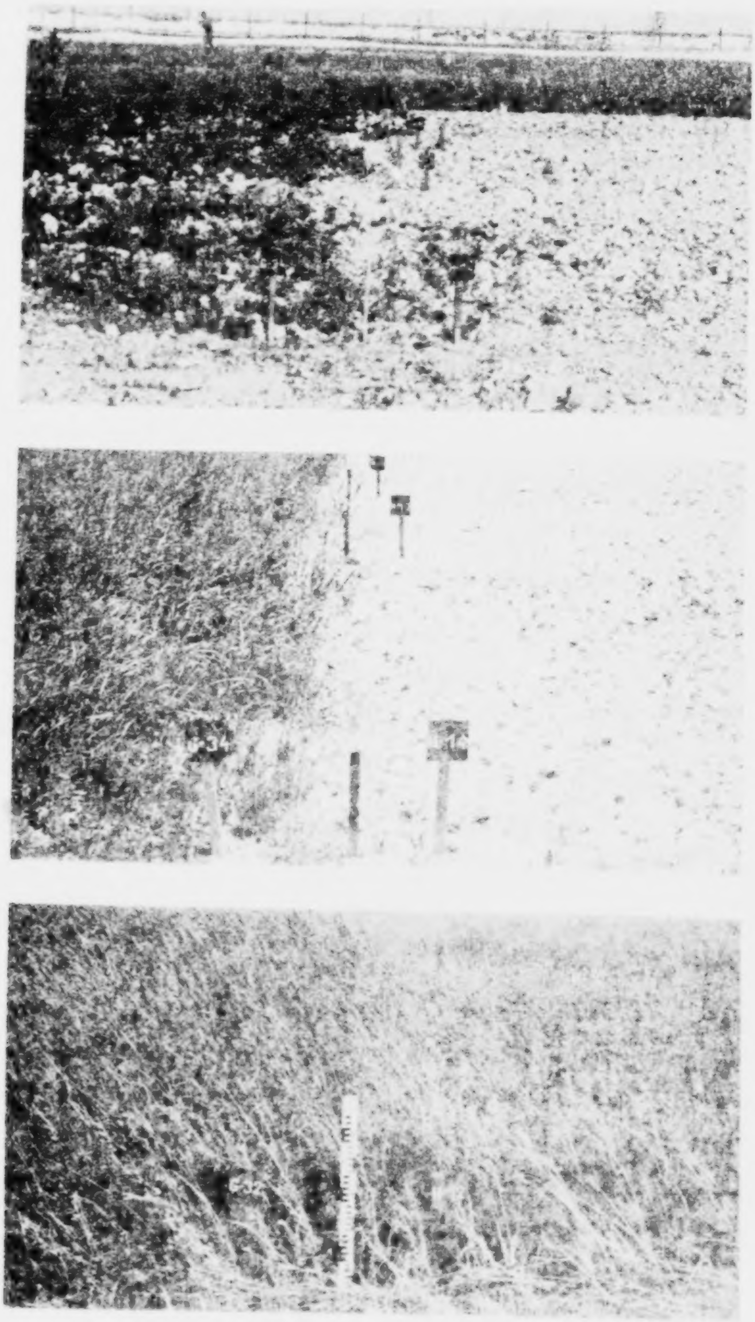
2) All plots were harrowed after applying fertilizers

3) All plots were harrowed after reseeding.

c) Supplementary seeding

Mix 1)	On plots D, E, F, G, K, I, O:		Seeding rate
	- sairfoin (Onobrychis viciaefolia)	-	280 kg/ha

Mix 2) On plots A-O - mixture of grasses with nitrogen - forming plants:



year I

year II

year III

Fig. no. 22. Field experiments in Konin – cultivation of sainfoin and crown vetch (H-1), and mixtures of legumes with grasses (G-3) on ashes with addition of farm manure + NP (G-3) or green manure + N2P in the I,II and III year of growth.

	Seeding rate
- meadow fescue (Festuca pratensis)	24 kg/ha
- orchard grass (Dactylis glomerata)	8 kg/ha
- smooth bromegrass (Bromus inermis)	24 kg/ha
- June meadowgrass (Poa pratensis)	10 kg/ha
- red fescue (Festuca rubra)	34 kg/ha
- white clover (Trifolium repens)	6 kg/ha
- alfalfa (Medicago lupulira)	14 kg/ha
- white melilot (Melilotus albus)	6 kg/ha
- tall rye grass (Arrhenatherum elatius)	26 kg/ha
- bentgrass (Agrostis stolonifera)	8 kg/ha
Total	160 kg/ha

Mix. 3) On plots A-0 - mixture of nitrogen-forming plants with grasses:

- lucerne (Medicago sativa)	seeding rate	72 kg/ha
- orchard grass (Dactilis glomerata)	- " -	12 kg/ha
	Total	84 kg/ha

Mix 4) On plots A,B,C:

- white melilot (Melilotus albus) seeding rate 100 kg/ha

All seeds of nitrogen-forming plants were treated with nodule bacteria. As noted earlier, the spring of 1976 was characterized at Konin by very low precipitation and prolonged cold weather. At the beginning of June (in normal years the time for the first harvest of the grasses, the seeds had only begun to germinate.However, in comparison to the results of the preceding year, this germination was quite satisfactory on treatment plots of the series A,B,C, (mixtures of grasses and nitrogen-forming plants) and G series (treatment with farm manure) where grasses were seeded.

On 7 Jun. 76 the plants were harvested from those plots where the development of vegetation permitted. Samples were used for chemical and for radiological analyses. The highest yields were obtained from the combined plantings of grasses and nitrogen-forming plants on plots treated with soil or with farm manure.

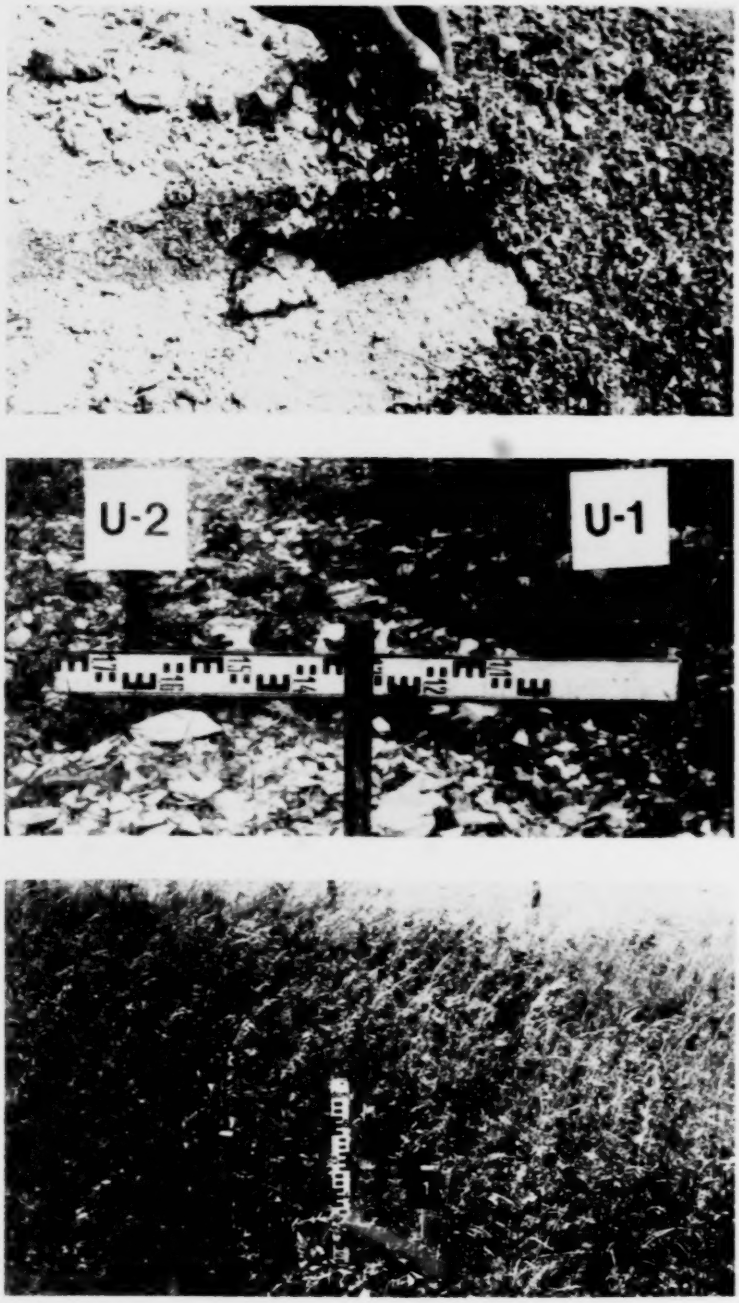

year I
year II
U-2
U-1
year III

Fig. no. 23. Consolidation of the disposal area surfaces in Konin with latex in a month after consolidation and in the I and II year of growth of legumes.

On the day after harvesting, the plots of series A through K were fertilized at the following rate:

- 50 kg/ha of N (110 kg/ha of 46 % (N) urea)
- 50 kg/ha of P_2O_5 (400 kg/ha of industrial fertilizer in a form containing 18 % super phosphate).

On 23 Sep. 76 the vegetation was harvested a second time. The highest yield of this harvest was obtained from the A-2 plot (covered with 20 cm layer of fertile soil and sown with grasses and nitrogen-forming plants), from B-2 and C-2 plots (10 or 5 cm layer of fertile soil sown with the same seed mixture) and from B-2 and C-2 plots (10 or 5 cm layer of fertile soil sown with the same seed mixture). No yields were obtained from plots D-1, E-1, E-3, F-1, F-3, G-1, K-1, K-3, I-1, I-3 and none from control plots (o series).

At the request of the sponsor and as was done at Halemba, fertilization of the treatment plots was eliminated in 1977 for one-half of the repititions. Therefore in the spring of 1977 mineral fertilizers and harrowing was conducted only on repititions 1 and 2. The rates of fertilizer applications were:

- 60 kg/ha of P_2O_5 (330 kg/ha of industrial fertilizer in a form containing 18 % superphosphate)
- 100 kg/ha of N (220 kg/ha urea containing 46 % N).

In the spring of 1977 at time of favorable precipitation and temperature, the growth of plants was satisfactory. The plants were harvested on 7 Jun. 77. The yield from many plots compare favorably with crops from surrounding fields or meadows which are intensively farmed. Yields from fertilized repetitions are usually several score (in per-cent) higher than from the unfertilized plots.

Immediately after harvesting, one-half of the repititions were again fertilized (only repetitions 1-2, of series A-K; no plots of the 0 series). The fertilization rate was:

- 60 kg/ha of P_2O_5 (330 kg/ha of industrial fertilizer containing 18 % superphosphate)

year I
year II
VI2
V 2
year III
VI2
V 2

Fig. no. 24. Silvan reclamation on the Halemba disposal area. Cultivation of locust tree in the I,II and III year of growth.

- 100 kg/ha of N (220 kg/ha of urea containing 46 % N).

In autumn of 1977 the second harvest was collected, and differences in yields from fertilized and unfertilized plots were measured.

The results characterizing the utility of the ash treatments for reclamation are presented in section 5 and 6 of this report.

FIELD EXPERIMENTS USING TREES AND SHRUBS - 1975-77

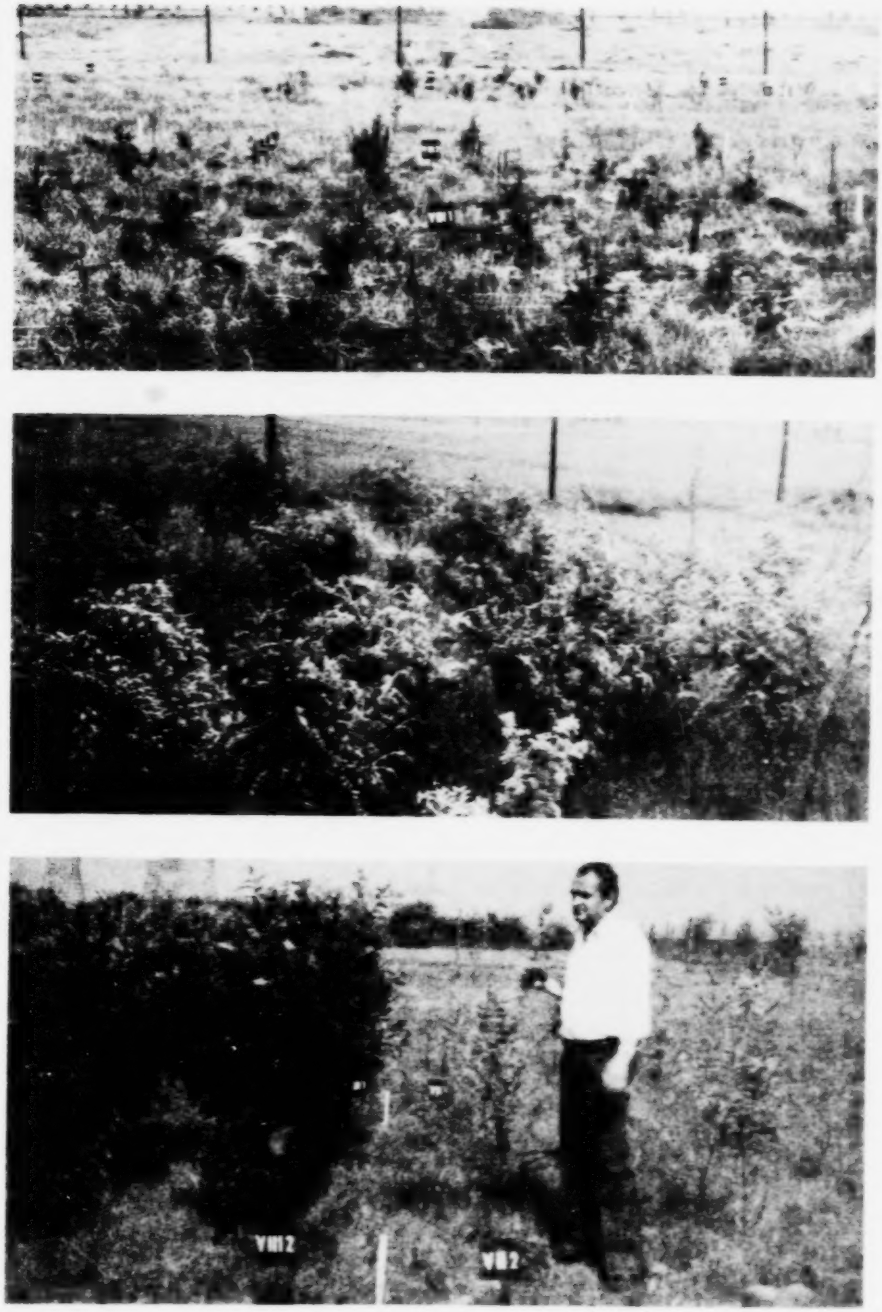
Halemba

Trees and shrubs were planted in the spring of 1975 in the combinations discussed above in chapter: Preparation of experiments using trees and shrubs. Weeds and grasses were cleared from the plots during the experiment period.

The first planting of birch (Betula verrucosa), larch (Larix decidua), and grey alder, (Alnus incana) did not survive at Halemba and new trees were planted on these plots. No fertilizers or ash treatments were added and the new trees were planted in the very same locations as the described first plantings. New poplar trees were also planted in place of those lost in plant series "II".

An additional test plot ("XI") was developed at Halemba usings cuttings of poplar shoots planted on four ash treatment combinations described as follows:

- plot XI-1 - pits covered with 20 cm layer of fertile soil and fertilized with 130 kg/ha of P_2O_5 in the form of granulated triple superphosphate (300 kg/ha)
- plot XI-2 - pits mixed with 100 m^3/ha bentonite and fertilized with 130 kg/ha of P_2O_5 in the form of granulated triple super phosphate (300 kg/ha)
- plot XI-3 - pits mixed with 10 t/ha of high moor peat (calculated in terms of the air-dry mass) fertilized with 130 kg/ha of P_2O_5 in the form of granulated triple superphosphate (300 kg/ha)


year I

year II

year III

Fig. no. 25. Silvan **reclamation** on the Halemba disposal **area.** Cultivation of pea shrub in the I, II and III year of growth.

- plot XI-4 - pits mixed with 130 kg/ha of P_2O_5, in the form of granulated concentrated superphosphate (300 kg/ha).

Following these additions, all plots were turned over and left for the winter. In the spring of 1976 - before the growing season, the area was raked and the poplar shoot cuttings planted in a spring of 1 x 0.5 m (40 shoot cuttings to 1 plot). Plots of the X series (willow shoot cuttings), and this new XI series (poplar shoot cuttings) were fed with nitrogenous fertilizers - 50 kg/ha of N as urea.

All of the trees and bushes were also supplied with nitrogenous fertilizers in following doses (per tree or bush):

- plots of I and II series (poplars) - 55 g for 1 tree
- plots of III to IX series (remaining types of trees and bushes) - 7 g of N per one cutting.

After fertilizing, the area around the plants was hoed. In the autumn of 1976, an analysis of the plants was made with the objective of determining the success of plantings, in terms of vigor and increments of growth. Most dead plants were replaced with new cuttings. In the spring of 1977 the dead poplars and willows were also replaced.

In 1977 the plants were not fertilized and the cultivation was limited to removal of weeds and to hoeing to break up the crust on the surface of the "soil".

In autumn of 1977 the plants were examined for the second time to determine the success of the reclamation method. The results are presented later in this report.

Konin

The first leaves of about 50 percent of those trees that were planted at Konin dried out shortly after the initial sprouting in the spring of 1975. Leaves reappeared on some plants in June however these also dried out. The number of live specimens gradually decreased so that in autumn only the following specimens remained alive:

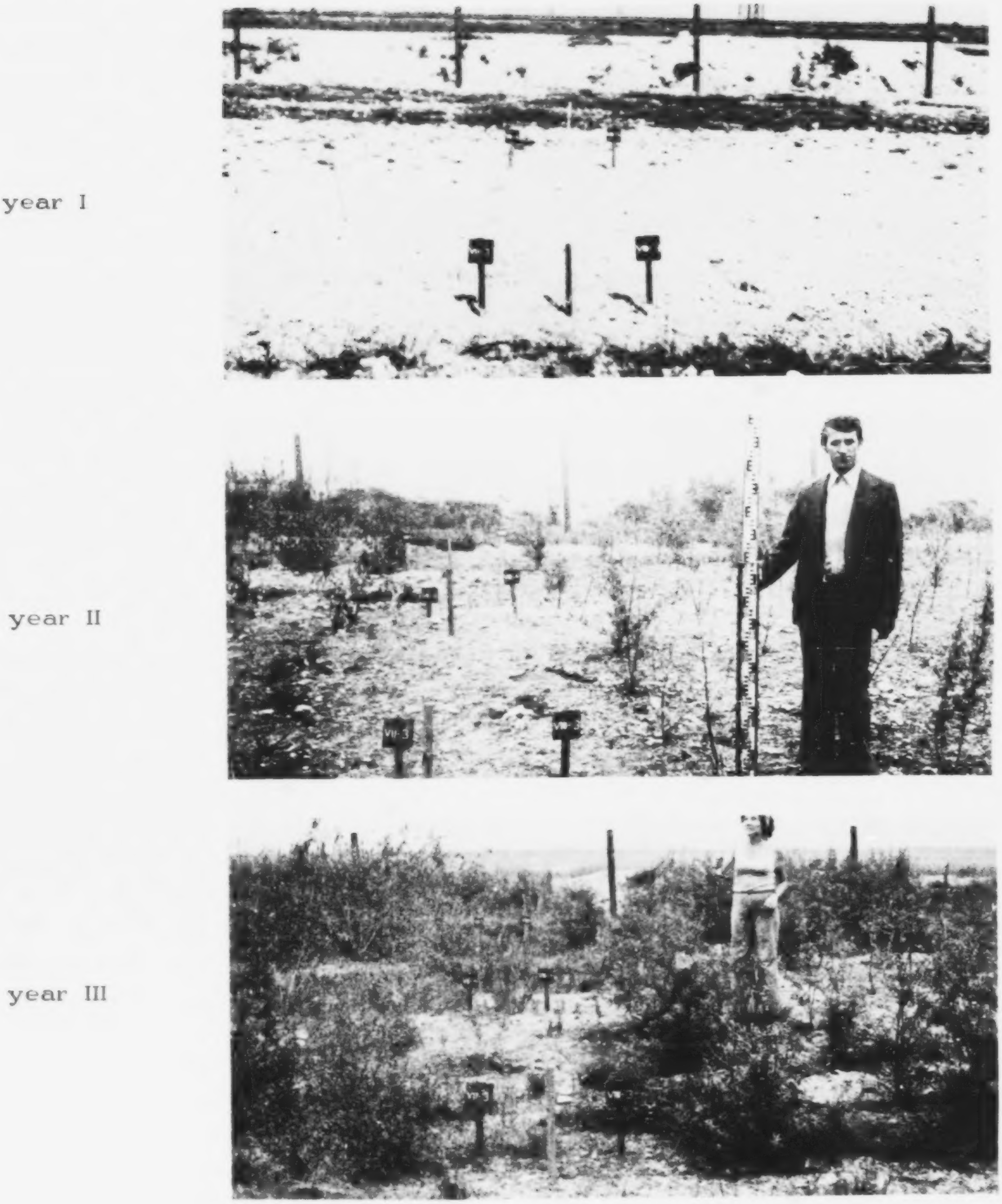

year I
year II
year III

Fig. no. 26. Silvan reclamation on Konin disposal area. Cultivation of sea buckthorn in I, II and III year of growth.

- I series - 4 specimens of poplar (with shoots and dry coronas)
- II series - 11 specimens of poplar (with shoots - 5 spec. or turned green tree tops - 6 spec.)
- IV series - 1 cutting of grey alder (with shoots)
- VI series - 3 cuttings of locust tree
- VIII series - 4 cuttings of sea buckthorn
- IX series - 12 cuttings of pea shrub.

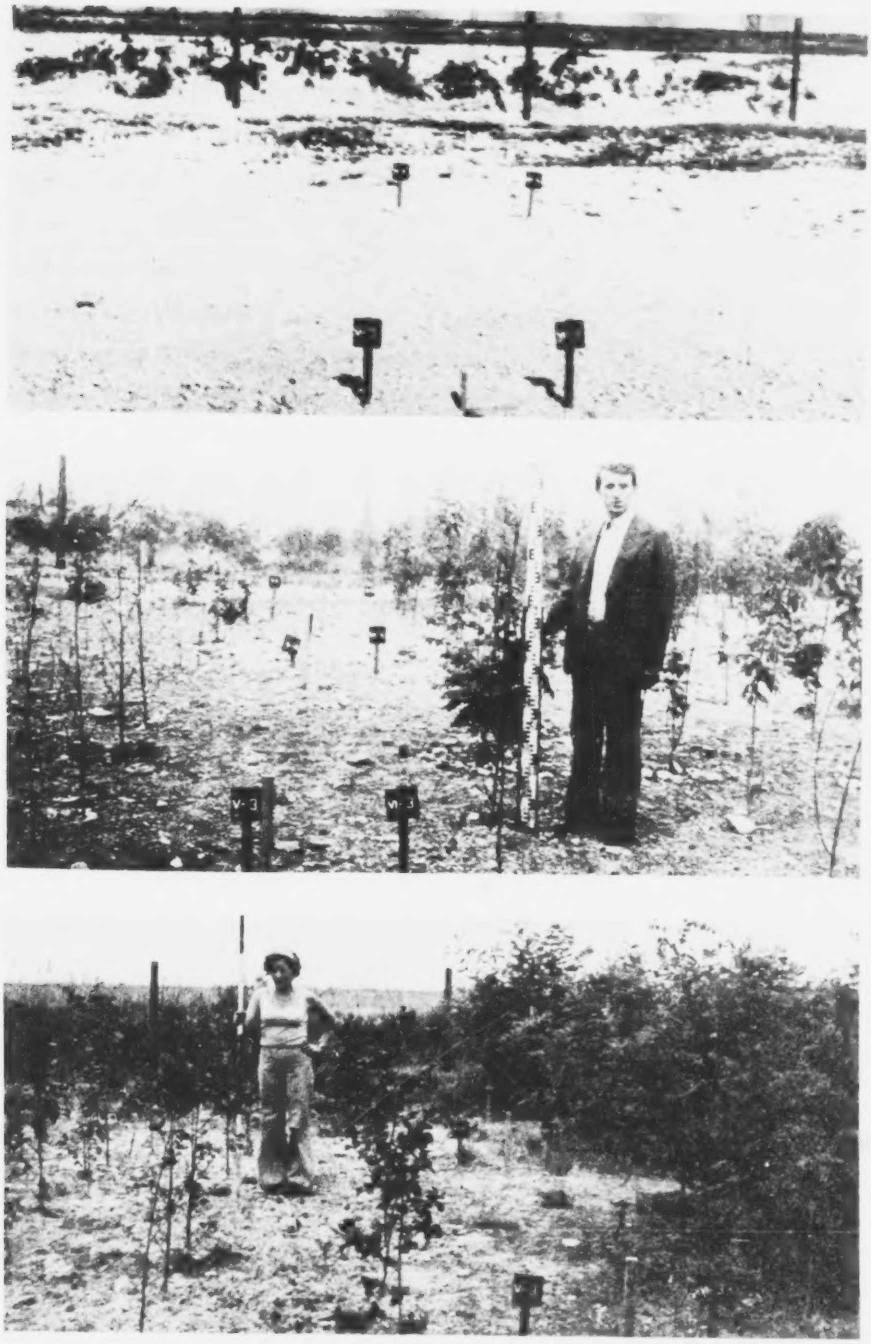
By the end of the 1975 growing season the plantings of shoot cuttings survived as follows:

- X-1 plot - 26 shoot cuttings (of 40 planted) attained increases in heights of 22-54 cm (average 35 cm)
- X-2 plot - 11 shoot cuttings attained increases in heights of 13-26 cm (average 20 cm).

In view of these unsuccessful attempts to introduce trees and bushes in the spring (this may be explained by the drought, the loosening of the ash before planting, and the high salinity of the ash), it was decided to repeat the experiment in autumn 1975, and to add a fifth combination of culture based on filling the pits (dug in the ash) entirely with soil. The pits for previous plantings of trees and bushes were completely dug out and filled with dressing prepared according to the treatments described in chapter: Preparation of experiments, using trees and shrubs. Trees and bushes were planted (except larch) a few days after preparation of the pits. Larch was planted in the spring of 1976.

Since rainfall was low again in the spring of 1976, the cuttings were watered a few times. During the summer, areas around plantings were hoed. In autumn of 1976 measurements of growth and health were made. Dead plants were replaced with new plants as at Halemba.

The losses of poplar shoot cuttings in X series were also made up for with new cuttings during 1977. The entire area was cultivated in 1977 to remove weeds and to break up a crust that had formed. In autumn measurements of growth and health were made.



year I

year II

year III

Fig. no. 27. Silvan reclamation on the Konin disposal area. Cultivation of locust tree in the I, II and III year of growth.

ADDITIONAL EXPERIMENTS TO DETERMINE THE EFFECT OF SURFACE TREATMENTS USED

Evaluations of the success of latex compounds for stabilizing the ash surfaces were not possible at either Halemba or Konin since insufficient vegetation was available for harvest and evaluation. In order to evaluate the use of latex, additional plots were established at Konin in the spring of 1976 to test various application rates of latex. The plots measured 4 x 9 m and consisted of one repetition of each application rate (fig. 16 and 23).

a) Cultivation and fertilization

In the autumn of 1975 the plot area at Konin was plowed. In the spring of 1976 the area was harrowed and fertilizers were added to the entire area as follows:

- 60 kg/ha of P_2O_5 (in the form of triple granulated superphosphate);
- 50 kg/ha of N (in the form of urea).

b) Seeding (fig. 16)

Approximately 14 days after fertilizing, two different seed mixtures were sown. These were:

Mix 1) on plots U-1, U-2 and U-3 consisting of:

		seeding rate
- meadow fescue (Festuca pratensis)	-	24 kg/ha
- orchard grass (Dactylis glomerata)	-	8 kg/ha
- smooth bromegrass (Bromus inermis)	-	24 kg/ha
- June meadowgrass (Poa pratensis)	-	10 kg/ha
- red fescue (Festuca rubra)	-	34 kg/ha
- white clover (Trifolium repens)	-	6 kg/ha
- alfalfa (Meedicago lupulina)	-	14 kg/ha
- white melilot (Melilotus albus)	-	10 kg/ha

		seeding rate
- tall rye grass (Arrhenatherum elatius)	-	26 kg/ha
- bentgrass (Agrostis stolonifera)	-	8 kg/ha
Total		164 kg/ha

Mix 2) on plots U-4, U-5, U-6 a mixture of a grass and a forb consisting of:

- lucerne (Medicago sativa)	-	72 kg/ha
- orchard grass (Dactylis glomerata)	-	12 kg/ha
Total		84 kg/ha

c) Application of latex solutions

Latex compound LBSK-5545 in solution with water 1:10 was applied at the following rates:

1) single thickness of 0.10 mm; rate of 0.10 dm^3/m^2 on plots U-2 and U-5;

2) double thickness of 0.20 mm; rate of 0.20 dm^3/m^2 on plots U-3 and U-4;

3) control, without latex on plots U-1 and U-6.

d) During the germination and growth of plants in 1976, no differences were observed on any particular plots that could be interpreted as a positive or negative effect of latex. The latex formed a crust 3 to 8 mm thick on the surface of the ash. This crust remained until autumn. In the spring of 1977 the crust had disappeared and any differences in vegetative growth observed thereafter could only be attributed to the differences in seed mix.

e) On the 7 June 77 the plants were cut and the green mass was weighed.

The yield data results (table 18) show positive influence of latex on the crop of grasses and harmful effects on the growth of lucerne. To obtain definite data, one would have to carry out additional and more specific tests. On the basis of performed experiments one can state that optimum rate of latex amounts to 0.10 mm, i.e. 0.10 dm^3/m^2 of consolidated surface.

Table 18

Treatments	Yields of green mass from plots in kg/36 m2			
	plots with grass		plots with grass and forb	
	No.	kg/36 m^2	No	kg/36 m^2
I-st cut in 1977				
Control	U-1	29.00	U-6	26.60
Latex - 0.10 mm thick	U-2	38.30	U-5	23.60
Latex - 0.20 mm thick	U-3	35.80	U-4	13.00
II-nd cut in 1977				
Control	U-1	20.60	U-6	37.20
Latex - 0.10 mm thick	U-2	21.70	U-5	38.90
Latex - 0.20 mm thick	U-3	10.80	U-4	26.70
Total				
Control	U-1	49.60	U-6	63.80
Latex - 0.10 mm thick	U-2	60.00	U-5	62.50
Latex - 0.20 mm thick	U-3	46.60	U-4	39.70

SECTION 8

PROPERTIES OF ASHES, OF PRODUCED SOILS AND OF HARVEST

CHEMICAL AND MINERALOGICAL COMPOSITION OF ASHES

Methodology

Chemical and physical analyses of fly ash ("fresh" ash) and a mix of fly and bottom ash were performed according to the following procedures:

a) SiO_2 - through fusion of sample with sodium carbonate and emission of silicic acid by means of double evaporation with hydrochloric acid [46].

b) Al_2O_3 - with II complexometric method through direct titration of aluminium ions with solution of bi-sodium versenate against coper complexonian [46].

c) Fe_2O_3 - with complexometric method through direct titration of iron ions with bi-sodium versenate against salicylic acid [46].

d) TiO_2 - through titanium oxidation with hydrogen peroxide in the presence of sulphuric acid and measurement of intensity of yellow-orange colouring of formed pertitanyl compound [46].

e) CaO - gravimetrically through precipitation of calcium in a shape of oxalate [46].

f) MgO - gravimetrically through emission of magnesium in a form of ammonium - magnesium phosphate with the aid of bi-ammonium phosphate in the presence of ammonia [46].

CHEMICAL COMPOSITION OF ASHES

(weight percent)

Table 19

	Component	Konin						Halemba					
		fresh fly ash from electro-filters			ash from disposal under reclamation			fresh fly ash from electro-filters			ash from disposal under reclamation		
		K-4 from chute of the 8 and 9 boilers	K-5 from chute of 8 and 9 boilers	K-6 from 10 and 11 boilers chute	K-1 from experimental field by the gate	K-2 from experimental field by pipeline outlet of pulp discharge	K-3 from central part of sedimentation basin	H-4 from central chute, Sep. 29. 75	H-5 from medial chute Sep. 30, 75	H-6 from medial chute Dec. 12, 75	H-1 experimental field by the hut	H-2 experimental field mediate part of sedimentation basin	H-3 by outlet of pulp from pipeline
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	SiO_2	39.18	39.87	36.26	75.22	90.53	53.88	47.47	47.05	47.26	49.04	47.48	46.50
2.	Al_2O_3	10.10	10.36	4.22	2.23	0.53	3.05	27.49	27.18	26.56	22.43	23.44	21.84
3.	Fe_2O_3	5.80	5.75	7.70	2.60	2.60	3.65	6.45	6.45	6.45	10.05	11.15	11.20
4.	TiO_2	1.74	1.63	1.16	0.55	0.45	0.62	1.13	1.16	1.25	1.05	1.02	0.90
5.	P_2O_5	0.09	0.11	0.07	0.02	0.01	0.03	0.28	0.29	0.29	0.27	0.29	0.29
6.	CaO	28.02	27.94	34.13	8.45	3.25	18.23	4.21	4.41	4.41	4.96	5.00	6.55
7.	MgO	5.32	4.78	7.28	0.82	traces	1.58	2.49	2.69	2.52	2.49	2.55	2.38
8.	Na_2O	0.26	0.28	0.14	0.06	0.03	0.06	0.80	0.82	0.82	0.42	0.40	0.42
9.	K_2O	0.22	0.22	0.16	0.10	0.10	0.10	2.56	2.50	2.56	2.38	2.34	2.34
10.	SO_3	8.30	8.17	7.79	1.32	0.48	0.80	0.49	0.40	0.57	0.53	0.65	0.51
11.	S(total)	3.41	3.35	3.12	0.53	0.29	0.38	0.23	0.24	0.28	0.21	0.29	0.23
12.	free Fe_2O_3	5.72	5.54	7.68	2.60	2.48	5.44	4.28	4.28	4.16	7.34	8.20	8.88
13.	sintering losses	0.85	1.01	1.05	8.40	2.18	15.66	6.76	7.02	7.21	6.37	5.64	6.94

SPECTROGRAPHIC ANALYSIS OF ASHES

(concentration in ppm)

Table 20

	Com-ponent	Konin						Halemba					
		fresh fly ash from electrofilters			ash from disposal under reclamation			fresh fly ash from electrofilters			ash from disposal under reclamation		
		K-4 from the 8 and 9 boilers	K-5 from 8 and 9 boilers	K-6 from 10 and 11 boilers	K-1 from experimental field by the gate	K-2 from experimental field by pulp outlet discharge of pipeline	K-3 from central part of sedimentation basin	H-4 from medial chute, Sep.29, 75	H-5 from medial chute Sep. 30, 75	H-6 from medial chute Dec. 12, 75	H-1 experimental field by the hut	H-2 experimental field central part of sedimentation basin	H-3 by pipe outlet of pulp
1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Ba	450	620	800	150	500	100	680	680	800	1080	1200	1150
2	Fe	30	30	30	30	30	30	30	30	30	30	30	30
3	Co	30	30	30	30	30	30	30	30	30	30	30	30
4	Cr	50	70	40	20	30	20	50	50	60	40	50	40
5	Cu	40	50	50	40	70	10	70	100	100	90	80	70
6	Ga	10	20	10	10	10	10	20	30	30	20	20	20
7	Ni	50	50	50	50	50	50	50	50	50	50	50	50
8	Pb	60	30	30	30	60	30	50	80	70	50	60	50
9	Mn	2100	3100	4000	750	860	1200	370	620	540	900	840	860
10	Sr	180	200	240	50	40	30	80	60	110	60	90	70
11	V	100	90	120	50	50	50	70	70	90	60	80	60
12	Zn	200	200	200	200	200	200	200	200	200	200	200	200

g) K_2O and Na_2O - photometrically [43]

h) S - through dissolution of sample in aqua regia and precipitation in filtrate of sulphates with solution of barium chloride [43]

i) P_2O_5 - colorometrically with vanadium - molybdenum method [43]

j) free Fe_2O_3 - in sodium citrate, employing reduction with hyposulphite - according to Jackson [43]

k) content of trace elements was determined on spectrograph.

Mineralogical - petrographic analysis was performed using:

optical microscopes, electron microscopes, Roentgen investigations, and spectroscopic investigations (infra-red).

The optical examinations were performed on powdered samples mixed with distilled water and fixed on glass slides with Canada balsam. Optical features were determined with a polarizing microscope (LABOVAL) with one nicol, and with crossed nicols. In order to determine the properties of transparent anisotropic and isotropic grains and opaque fragments, a planimetric analysis was made using an integration table (ELTINOR).

Dust particles were affixed to the carbonate - covered graticules for the electron microscopy analyses. The analyses were performed using a C. Zeiss - EFV microscope with an accelerating voltage of 75 kV.

Roentgen phase analysis was carried out using the powder method of Debye - Scherrer - Hull by means of diffractometer (TUR M-61). Samples were prepared for analysis in the shape of flat discs, pressed to diminish the effects of the preferred orientation of lamellar minerals. Diffraction images of samples were recorded within a range of 0-30°, using shift of counter GM 30°/min. and a 600 mm/h velocity tape feed. On the basis of measurements of interference positions on diffractograms their respective interface distances were computed. As a measure of intensity the area described by the reflexes was determined from the intensity. Infra-red spectroscopic investigations were made using the

TEST RESULTS OF MINERALOGICAL COMPOSITION OF ASHES FROM POWER PLANT KONIN

Table 21

Sample	Determination of sample	quartz (SiO_2)	Ca anhydrite	CaO	calcite ($CaCO_3$)	xonotlite ($5CaSiO_3 . H_2O$)	gyrolite ($2CaO) . 3SiO_2 . 2H_2O$)	Ca_2SiO_4	magnetite (Fe_3O_4)	hematite (Fe_2O_3)	amorphous substance
1	2	3	4	5	6	7	8	9	10	11	12
K-1	Ash from tested field	+++	-	-	+	+	-	-	-	-	(+)-
K-2	Ash from tested field	+++	-	-	+	+	-	-	-	-	(+)-
K-3	Ash from tested field	+++	+	-	++	-	+	+	+	+	+
K-4	Ash from el. prec.	+++	++	++	-	-	-	-	+	+	++
K-5	Ash from el. prec.	+++	++	++	-	-	-	-	+	+	++
K-6	Ash from el. prec.	+++	++	++	-	-	-	-	+	+	++

Explanation:

+++ - main component in tested sample
++ - secondary component
+ - accessory component
- - lack of component

TEST RESULTS OF MINERALOGICAL COMPOSITION OF ASHES FROM POWER PLANT HALEMBA

Table 22

Sample	Sample determination	quartz (SiO_2)	gypsum ($CaSO_4 . 2H_2O$)	mullite ($3Al_2O_3 . 2SiO_2$)	magnetite (Fe_3O_4)	hematite (Fe_2O_3)	amorphous substance
1	2	3	4	5	6	7	8
H-1	Ash from tested field	+++	+	++	+	+	+++
H-2	Ash from tested field	+++	+	++	+	+	++
H-3	Ash from tested field	+++	++	+	++	+	++
H-4	Ash from el. prec.	+++	+	+	+	+	++
H-5	Ash from el. prec.	+++	+	++	+	++	+++
H-6	Ash from el. prec.	+++	+	++	+	+	+++

Explanations:

+++ - main component in the tested sample
++ - secondary component
+ - accessory component

Zeiss UR-10. Samples were prepared for analysis in the form of pressed tablets of KBr. Absorption images were recorded within range of wave numbers of 400 - 1800 and 3000 - 3800 cm^{-1}. For the range of 400 - 700 cm^{-1} the prism was made of KBr, for 700 - 1800 cm^{-1} - the prism was constructed of NaCl, and for the range 3000 - 3800 cm^{-1} the prism was made of LiF.

Chemical composition of ashes

The results of analyses are presented in tables 19 and 20.

Analyses of fresh fly ash from Konin indicate a large difference in Al_2O_3 and CaO concentrations which are a function of size characteristics of the ash and the type of coal. The results are influenced by contamination of the coal with gob, (clays and tertiary sands). In a process of hydraulic sluicing such as occurs to transport the ash to the disposal area, CaO and MgO are leached from the ashes, therefore, the chemical composition of ashes in the disposal basin changes from that of fresh ash. The proportion of SiO_2 increased from 36 - 39 % to 54 - 90 % (table 19), dependent on the place of sample collection in relation to the outlet of the pipeline transporting the slurry to the disposal basin. Simultaneously, the content of Cao and Mgo decreases from 32-41 % to 3-20 %. The content of SO_3 was diminished on the Konin ash. This may be related to leaching of calcium, magnesium, sodium and potassium sulphates, and also to the higher sulphur content of lignite coal at Konin. The extent of leaching of ash depends to large degree on the total dissolved solids content of the water used for transport. When the water is recycled, it becomes saturated with dissolved salts, and further leaching of ashes is limited. Chemical (table 19) and spectrographic analyses (table 20) indicate that the soils created from treatment of Konin ashes are characterized with sufficient macro- and microelements such as Ca, Mg, Fe, Mn, Zn, Cu, Co. However, these may not be available to plants due to alkaline reaction of these elements within the ash.

The changes in chemical composition of ashes derived from Halemba bituminous coal is not so great as that of ash from Konin (table 19).

In contrast to the Konin ashes, ash from bituminous coal contains 2-3 times more Al_20_3 and 4-7 times less Cao. The content of Mg0 is 2-3 times less. The minimal change in Ca0 and Mg0 concentrations between fresh ash and ashes collected from the disposal basin indicate only minor leaching by the transport fluid. This conclusion is borne out by the Na_20 and K_20 analyses. The ashes from Halemba seem to have higher Cu, Zn and Pb concentrations than Konin. However the manganese content was lower (table 20).

Mineralogical composition of ashes from Halemba

X-ray tests of fresh ashes of bituminous coal, taken from electric precipitators of Halemba power plant samples (table 19) indicate that the main mineral component is silica. Significant quantities of gypsum and mullite ($CaSO_4 \cdot 2H_20$ and $Al_6Si_20_{13}$) were also measured. Magnetite (Fe_30_4) and hematite (Fe_20_3) occurred in smaller quantities. A diffuse diffraction band in the range of 4-10° indicates the presence of an amorphous substance, or "glaze". Spectroscopic tests (infrared) indicate that the main component of samples is a silicate glaze. Quartz (crystalline) appears in trace amounts. Mullite is quite clearly present. Its grain are small and either square in cross sections (up to 15 mm square), elongated, stick - or pin-like. The silica glaze occurs in spheres which are generally colourless, but which are sometimes cream-yellow or brown coloured. The diameters range from 20 to 60 μ.m.

The prevalance of quartz grains is notable in sample H-6 (table 22.) Ash at Halemba also contains hematite in the form of lamellae, tablets, or rhombohedrons with sharp outlines. Magnetite also appears but in the shape of single, fine rectangular or ortorhombic crystals.

The phase composition of all the ash samples collected at Halemba (samples H-1, H-2, H-3) is similar. The main crystalline component is guartz. Amounts of gypsum ($CaSO_4 \cdot 2H_20$) and mullite ($Al_6Si_20_{13}$) are present. Magnetite (Fe_30_4) and hematite (Fe_20_3) occur in lesser quantities. The amorphous substance, a silica glaze, occurs in all samples.

Optical microscopy confirms that main components of the H-3, H-4 and H-6 samples are glaze and mullite. Also identified were quartz and small amounts of calcium carbonate and sulphate. A significant proportion of these samples consisted of opaque chips which are difficult to identify with optical microscopy.

Additional observations of sample H-3 using the electron microscope showed that these opaque particles had spherical or ellipsoidal outlines and were opaque to the stream of electrons. These characteristics suggest that the particles are mullite.

Mineralogical composition of ashes from Konin

The main crystalline component of ashes derived from lignite (sampled from electric precipitators of Konin power plant) is quartz. X-ray tests further indicate significant quantities of anhydrite ($CaSO_4$) and CaO. Hematite (Fe_2O_3), and magnetite (Fe_2O_4) are present in smaller amounts. The diffraction lines of hematite are more intensive than of magnetite. The diffraction diagrams of samples within the range of 4-10° is characterized by a wide diffraction band, representing an amorphous substance. This band is clearly divided into 2 maxima of values 9.5 and 7.4 Å. This may indicate a partial crystallization of glaze substance leading to formation of a gyrolite type or other hydrated calcium silicate.

Spectrogram of K-4, K-5 and K-6 samples (ashes from the precipitators) differ clearly from samples K-1, K-2 and K-3 (ashes from the disposal area). Analyses showed absorption within a range band 800 to 1000 cm^{-1}, indicating the presence of silicates. The presence of carbonates and anions associated with the quartz was indicated by responses at wave length of 1430 cm^{-1} and a 680, 615, and 595 cm^{-1}, respectively.

Observations using the micro scope indicated the presence in samples 4, 5, and 6 of glaze, CaO, smaller amounts of calcium carbonate and calcium sulphate and opaque fragments with spherical sections. The size of the quartz grains varies greatly from 200 x 150 um to 40 x 30 um.

A considerable portion has isometric forms with spherical section, and is either colourless or more rarely cream or brown coloured. Inside some of the spheresis a dispersed, black, opaque substance. This substance is assumed to be glaze, the diameters of which range from 20 to 50 um. Microscopic analysis shows this glaze to have square cross sections and to be comprised of gray grains of CaO. Carbonates in small spheres with diameters under 10 um. Anisotropic crystals of calcium sulphate ($CaSO_4 \cdot 2H_2O$) were observed around the edges of these quartz crystals.

The major crystalline constituent in samples of ashes taken from disposal area (samples K-1, K-2, K-3) is quartz. Small X-ray reflections indicate the presence of unknown admixture of xonotlite ($5CaSiO_3 \cdot H_2O$) - hydrated calcium silicate. Some samples also contain gyrolite ($2CaO \cdot 3SiO_2 \cdot 2H_2O$) and calcium silicate ($Ca_2SiO_4$). Gypsum is also likely present. An intensive diffraction band within the 4-10° range again testifies to the presence of an amorphous substance (glaze).

Infrared spectroscopic tests identified the carbonate as calcite. The 600-670 cm^{-1} bands visible on spectrograms of K-3 sample probably represent a small amount of calcium sulphate.

Mineralogical - petrographic tests showed that samples collected from the ash disposal area show a preponderance of minerals including quartz, calcite, CaO xonotlite, gyrolite, and calcium silicate than do fresh ash samples taken from the precipitators. This change may be explained as the result of: (1) differential sorting of the particles after discharge in to the settling basin, and (2) chemical and physical changes occurring principally in the ash disposal area ("weathering"). During the process of hydraulic transport and weathering there follows an increase in the calcite, xonotlite and gyrolite content at the expense of anhydrite and calcium oxide.

RADIOACTIVITY OF ASHES

Method of investigations

Investigations of radioactive components of the ash were performed on selected samples of both ashes and water extracts prepared according to chapter: Polution of waters and in agreement with recommendations of International Atomic Agency - I.A.E.A. and International Commission of Radiological Protection - I.C.R.P.

General characteristic radioactivity alpha beta and gamma was determined with the method of a "thick layer" using the following measuring systems:

1) MPS-3, scintillator Zn (Ag)
   $U = 1200$ V, own run $0.2 - 0.3 \frac{\text{impulse}}{\text{min.}}$
   - alpha radiation

2) LL1 with UCB-2 head
   $U = 990$ V, own run $1{,}38 \frac{\text{impulse}}{\text{min.}}$
   - beta radiation

3) PE-1, scintillation probe, SSU-4,
   $U = 980$ V, own run $310 \frac{\text{impulse}}{\text{min.}}$
   - gamma radiation.

The time of samples and of background measurement was determined on the basis of Putman formulae. Determinations of ^{226}Ra was based on dissolution in hydrochloric acid and separation of evolved chlorides from the insoluble parts. Then the excess hydrochloric acid was evaporated and chlorides dissolved in distilled water. The content of radium in water was determined with the Goldin method. The investigations were performed in 1975 (spring and autumn) and in 1976 (autumn) with the objective of studying any changes in radioactivity occurring during reclamation.

Results of tests

Alpha and beta radioactivity of ashes and of mixtures of ashes treated to improve the soil properties presented in tables 23 and 24. The radioactivity in natural soil is also presented for comparison.

On the basis of these investigations it cannot be said whether the reclamation treatments affect the radioactivity of the ash.

Rather it seems that the radioactivity fluctuations are related to the fall-out of ashes emitted by the stacks of nearby coal-fired power plants. This thesis seems plausible in view of the fact that increased alpha activity on treatment plots at Konin (samples taken on the 6 Sep 76) followed after exceptionally high particulate concentrations were observed (113 t/km^2, in May, 1976) and after relatively high particulate levels were observed during the air quality sampling period prior to collection of the ash samples. The high radioactivity of the fly ash confirms analysis of fresh fly ash (table 26). Alpha activity in the ash was 43 times higher than in soil, and gamma activity was as much as 57 times higher.

The alpha and gamma activity of water extracts of all ash samples (tables 25 and 26) is higher than the control sample of soil. The highest alpha activity was measured:

- at the Halemba site on treatment plots with double fertilization (245.5 pCi/dm^3, table 25);
- at the Konin site also on plots with double fertilization and on those plots covered with 5 cm layer of soil (66.2 pCi each); the III series of tests indicated a few times higher activity (e.g. 440.7 pCi/dm^3 on plots covered with 20 cm layer of fertile soil).

Highest gamma activity was found:

- at Halemba on plots covered with 10 cm layer of soil (138.8 pCi/dm^3)
- at Konin on plots treated with farm manure (105.6 pCi/dm^3).

Fresh ash from the electrostatic precipitators of the power plant Konin contained the highest alpha and gamma activity (alpha activity 1059.1

CHARACTERISTIC RADIOACTIVITY OF ASHES FROM HALEMBA POWER PLANT

I series of tests - samples taken on Jun. 6, 75
II series of tests - samples taken on Sep. 9, 76

Table 23

Sample marking Number of plots	Description of sample	Test series	Alpha activity pCi/g	Standard deviation ±	Gamma activity pCi/g	Standard deviation ±	Potassium activity pCi/g	Standard deviation ±
1	2	3	4	5	6	7	8	9
	A. Material used for treatments							
A-0	Soil used to cover disposal in Halemba (plots A-C) - "control"	I	26.81	5.8	20.60	5.1	20.5	2.0
	B. Fresh ash							
00	Ash from electrofilters	I	42.00	14.0	71.51	14.0	28.0	2.1
01	Ash from sedimentation basin prior to reclamation treatments	I	74.12	12.0	1.3	12.3	20.1	2.5
	C. Ash under reclamation							
0	Ash without fertilization (control)	I III	20.00 146.9	3.6 6.9	26.66 traces	4.9 .	30.0	1.3
A	Ash + 20 cm layer of soil + NPK	I III	24.00 79.10	4.8 7.3	47.87 99.9	8.0 3.6	21.6	1.8
B	Ash + 10 cm layer of soil + NPK	I III	11.04 372.9	2.1 15.8	138.77 traces	14.0 .	14.3	1.7
F	Ash + mountain peat + NPK	I III	294.9 traces	18.4 .	56.00 62.60	8.0 7.1	17.3	2.0
G	Ash + farm manure + NPK	I III	74.12 440.7	8.3 1.6	52.12 traces	6.4 .	32.4	1.8
H	Ash + N2PK	I III	26.81 90.4	10.3 5.2	50.30 traces	10.2 .	25.8	3.0

CHARACTERISTIC RADIOACTIVITY OF ASHES FROM KONIN POWER PLANT

I - series of tests - samples taken on the May 13, 75

III - series of tests - samples taken on the Sep. 6, 76

able 24

Sample marking / Number of plots	Description of sample	Test series	Alpha activity pCi/g	Standard deviation ±	Gamma activity pCi/g	Standard deviation ±	Potassium activity pCi/g	Standard deviation ±
1	2	3	4	5	6	7	8	9
	A. Material used for treatments							
A-0	Soil used to cover disposal in Konin (plots A-C) - "control"	I	26.81	5.8	20.60	5.1	20.5	2.0
	B. Fresh ash							
K-01	Ash from sedimentation basin prior to reclamation treatments	I	42.00	4.6	30.00	2.7	30.3	2.8
	C. Ash under reclamation							
0	Ash without fertilization (control)	I	11.04	2.0	21.00	1.9	24.0	3.7
A	Ash + 20 cm layer of soil + NPK	I III	26.81 440.7	2.8 6.2	46.06 33.8	6.0 2.3	33.0	3.3
B	Ash + 10 cm layer of soil + NPK	I III	24.0 293.8	2.0 11.2	25.00 58.4	2.8 3.1	17.0	1.7
C	Ash + 5 cm layer of soil + NPK	I III	66.23 259.9	5.4 5.2	49.09 traces	7.8	23.0	2.8
D	Ash + tertiary sand + NPK	I III	2.0 293.9	2.0 1.8	20.60 traces	4.0 .	3.3	2.0
E	Ash + low bog peat + NPK	I III	38.50 226.0	6.3 2.3	32.00 58.4	7.0 8.1	13.4	5.0
F	Ash + mountain peat + NPK	I III	42.58 traces	5.7 .	52.00 97.0	5.6 2.3	23.4	4.6
G	Ash + farm manure + NPK	I III	26.81 282.5	4.3 6.1	38.78 105.6	3.8 1.8	37.0	4.8
H	Ash + N2PK	I III	66.23 90.4	6.0 2.3	15.77 traces	3.0 .	38.0	4.8
I	Ash + NPK	I	11.04	2.7	47.87	3.8	30.0	5.0

pCi/dm^3, and gamma activity 700.4 pCi/dm^3). The beta activity of ash was, in all cases, in concert with protective standards.

The levels of radioactivity measured are not, for that matter, considered hazardous for humans or animals. However the concentrations of ^{226}Ra in water in contact with ashes (table 27) are much higher than average ones observed in uncontaminated surface waters (0.2 - - 1.0 pCi/dm^3) and would be hazardous for drinking water supplies. For this reason prolonged contact of ashes with surface und underground waters should be considered as undesirable.

PHYSICAL AND AQUEOUS PROPERTIES OF ASHES

Halemba

Ashes of bituminous coal are characterized with a prevalence of fine particles (59 % with diameters of 0.1 - 0.02 mm) (table 29). For this reason they are comparable to soils classified as dusts. Treatments with certain amendments changed the particle size distribution very little.

The density of samples taken from different treatment and vegetation combinations in the field plots varied widely (2.22 to 2.56 table 30). The weight of untreated ash taken from a depth of 10-20 cm was 2.15 mg/cm^3. All samples taken from treatment plots show a higher specific gravity. The highest specific gravity (2.44 to 2.50) occurred in samples taken from plots with the 20 cm layer of soil. Similarly, increased specific gravity was observed on plots fertilized with bentonite. Repetitions of treatments gave relatively consistent specific gravity values.

Bulk density on all combinations is lower than 1 and fluctuates within limits of from 0.65 to 0.99 g/cm^3 (plots 0-3 and A-4, respectively, table 30). The lowest bulk density was measured for a sample collected at a depth of 20 to 30 cm below the surface. It is therefore concluded that the material was not compacted but was rather porous.

The capillary water capacity ranged from 46.4 percent (plot B-2), to 60.2 percent (plot I-3). The capacity appeared highest in untreated ash. Field water capacity ranged from 19 to 31.6 percent (table 30). In the majority of cases the field capacity comprised half the capillary capacity. Field water capacity is the amount of water which a soil is capable of retaining with capillary forces above the level of capillary rise. Therefore field capacity is considered the best indicator of water content in soil available to vegetation.

Konin

Lignite ashes from Konin region (collected from electric precipitators) contained 72 percent of material ranging between 0.10 and 0.02 (table 29). This ash would be classified as "dust". Samples of ash collected from the disposal area were classified as light loamy sands since they contained fewer dust-sized partices. Treatment with soil caused an increase in the content of larger particles. (table 29)

The results of specific gravity measurements (table 31) show little difference between plots. Weight by volume shows greater variation ranging 0.56 (samples from plot I-2) to 1.48 (plot A-4). Weight by volume of ash from deeper layers was 0.54. Additions of soil (A,B,C series), and of sand (D series) caused increases in weight. Series A plots did not show any particular variation in weight for the various seed mixtures.

The porosity of the samples can be grouped into two categories dependent on the degree of soil amendment (table 31):

- those treated with 20 and 10 cm of soil which show less than 50 % porosity
- all other treatments with porosity between 50 and 80 percent.

The capillary water capacity ranges from 26.4 to 58.2 percent and also reflects the effect of adding materials to the ash which initially has a high capillary water capacity. However, additions of soil and sand reduced the capacity while other treatments did not.

CHARACTERISTIC RADIOACTIVITY OF WATER EXTRACT AFTER 8-DAY CONTACT WITH ASHES FROM HALEMBA POWER PLANT

(in proportion: 1 kg of ash + 2 dm^3 of distilled water)

I series of tests - samples taken on Jun. 6,75
II series of tests - samples taken on Sep. 29,75
III series of tests - samples taken on Sep. 9,76

Table 25

Sample marking number / number of plots	Description of samples	Test series	Alpha activity pCi/dm^3	Standard deviation $\pm$	Beta activity pCi/dm^3	Standard deviation $\pm$	Gama activity pCi/dm^3	Standard deviation $\pm$
1	2	3	4	5	6	7	8	9
	A. Material used for treatments							
A-0	Soil used to cover disposal in Halemba (plots A-C) - "control"	I	24.3	5.0	17.0	3.0	13.8	4.0
	B. Fresh ash							
H-0C	Ash from electrofilters	III	199.5	6.3	34.6	6.9	385.9	16.3
H-01	Ash from sedimentation basin	I	27.6	2.9	27.8	3.2	40.3	1.9
		II	32.2	6.6	16.9	9.4	109.3	22.0
		III	30.0	6.8	0.0	.	46.1	18.3
	C. Ash under reclamation							
0	Ash without fertilization (control)	I	63.0	3.7	32.0	7.0	45.6	2.8
		III	83.3	6.9	0.0	.	60.0	8.9
A	Ash + 20 cm layer of soil + NPK	I	28.3	3.8	17.8	3.2	18.3	2.6
		II	38.7	7.8	26.4	5.3	8.24	1.6
		III	88.5	8.6	10.7	6.3	19.2	1.9
B	Ash + 10 cm layer of soil + NPK	I	58.2	4.3	26.0	4.6	49.3	6.1
		II	67.9	13.6	2.1	0.4	3.16	1.0
		III	104.3	6.7	5.9	8.3	146.1	8.1
C	Ash + 5 cm layer of soil + NPK	II	0.0	0.2	29.1	6.0	79.9	16.0
		III	111.8	6.6	14.8	6.9	22.6	16.3
D	Ash + bentonite + NPK	II	171.5	54.4	15.9	3.2	44.7	8.9
		III	87.8	61.3	17.5	6.6	28.3	6.8
E	Ash + low bog peat + NPK	II	134.1	27.0	1.47	0.3	68.1	13.7
		III	traces	.	3.60	0.8	0.0	.
F	Ash + mountain peat + NPK	I	45.3	3.2	24.0	2.8	63.7	8.3
		II	23.2	4.6	5.9	1.2	36.9	7.4
		III	27.3	5.3	10.5	3.6	42.1	6.6
G	Ash + farm manure + NPK	I	45.0	4.0	28.0	4.0	55.8	6.1
		II	77.[illegible]	15.6	5.0	1.0	9.08	1.9
		III	66.1	14.1	3.8	6.3	traces	.
H	Ash + N2PK	I	24.3	3.0	26.3	3.0	32.8	1.6
		II	245.5	50.0	16.2	3.3	14.9	9.0
		III	42.4	16.1	5.3	6.6	194.6	16.1
I	Ash + NPK	II	81.2	16.4	6.5	1.2	26.1	5.2
		III	85.6	13.2	60.5	1.1	48.8	4.9

The water field capacity may also be segregated into two groups:

- in A,B,C combinations it fluctuates from 14.0 to 20.3 percent
- in I and 0 combinations it exceeds 40 percent and fluctuates from 42.9 to 44.2 percent.

The first group reflects the influence of the soils.

The second group is more like heavy loams and clays, where the field capacity makes up more than 70 % of capillary capacity.

CHEMICAL AND SORPTION PROPERTIES

Halemba (table 32, 34 and 36)

The fresh ash from electrofilters is strongly alkaline (pH 12.0 - table 32). During the process of hydraulic sluicing, the pH decreases to about 9.1 after treatment of the resulting soils show pH ranging from 4.2 to 8.8 The most suitable pH for plants was measured in the plots treated with soil. Plots treated with organic and mineral matter showed trends back toward more alkaline conditions during the experiment. Only on plots covered with thick layers of soil did the "soil" undergo a shift toward acid conditions. Measurements of carbon showed quite high values (perhaps due to incomplete combustion in the power plant see table 32). Additional quantities of carbon were added in the form of soil, which contained 11.5 to 12.4 percent of C. During the course of the experiments, the humus horizon was enriched with carbon derived from the plants.

The content of assimilable P_2O_5 is high and effects of large doses of phosphatic fertilizers can be seen. However, a phosphorus deficiency remains for the plants.

The ash contains large amounts of K_2O and for this reason no potassic fertilizers were used. The K_2O concentrations of the plots decreased with time.

Content of water-soluble boron (table 34) is high only in fresh ash (9.2 - 15.0 ppm) samples suggesting removal of boron during hydraulic sluicing.

CHARACTERISTIC RADIOACTIVITY OF WATER EXTRACT AFTER 8-DAY CONTACT WITH ASHES FROM POWER PLANT KONIN (in proportion 1 kg of ashes + 2 dm^3 of distilled water)

I series of tests - samples taken on the May 13, 75
II series of tests - samples taken on the Sep. 25, 75
III series of tests - samples taken on the Sep. 7, 76

Table 26

Sample number / number of plots	Description of sample	Test series	Alpha activity pCi/dm^3	Standard deviation ±	Beta activity pCi/dm^3	Standard deviation ±	Gamma activity pCi/dm^3	Standard deviation ±
1	2	3	4	5	6	7	8	9
	A. Material used for treatments							
A-0	Soil used to cover disposal in Halemba (plots A-C) - "control"	I	24.3	5.0	17.0	3.0	13.8	4.0
	B. Fresh ash							
K-00	Ash from electrofilters	I	1059.1	212	23.9	4.8	700.4	140.0
K-01	Ash from sedimentation basin	I	99.2	18.3	49.0	7.2	34.9	3.7
	C. Ash under reclamation							
0	Ash without fertilization (control)	I	275.1	24.0	47.6	8.0	37.2	4.0
		II	0.0	.	14.4	2.9	9.37	1.9
		III	167.1	18.6	10.5	4.9	112.8	8.3
A	Ash + 20 cm layer of soil + NPK	I	103.8	18.3	32.2	2.8	43.2	3.8
		II	116.2	24.0	6.67	1.4	9.73	2.0
		III	49.1	31.6	traces	.	21.3	2.9
B	Ash + 10 cm layer of soil + NPK	I	23.6	5.8	18.1	3.7	19.5	3.0
		II	79.4	16.0	8.03	1.6	61.9	12.4
		III	298.9	6.9	29.1	4.9	traces	6.2
C	Ash + 5 cm layer of soil + NPK	I	24.0	6.1	90.0	2.5	28.0	2.9
		II	186.8	38.0	9.19	2.0	58.3	12.0
		III	158.6	18.0	0.0	.	141.8	9.6
D	Ash + tertiary sand + NPK	I	27.0	6.0	0.0	2.0	18.9	2.0
		II	165.2	33.0	5.54	1.1	154.3	30.0
		III	traces	.	3.30	16.1	216.7	18.3
E	Ash + low bog peat + NPK	I	90.5	12.3	23.3	3.7	42.4	3.8
		II	375.9	74.5	8.43	1.7	16.4	3.4
		III	199.0	3.8	3.44	4.9	42.1	9.2
F	Ash + mountain peat + NPK	I	45.0	5.7	72.7	2.8	43.5	4.0
		II	192.0	39.0	17.30	3.4	378.3	76.0
		III	349.1	16.3	9.83	6.3	524.0	18.1

Table 26 continuation

1	2	3	4	5	6	7	8	9
G	Ash + farm manure + NPK	I	65.9	6.8	116.7	12.0	83.9	2.9
		II	206.4	42.0	24.80	5.0	235.1	48.0
		III	445.3	16.7	10.5	6.9	66.2	21.3
H	Ash + N2FK	I	65.2	6.8	137.6	8.0	39.0	3.9
		II	180.0	36.0	0.16	1.3	479.2	96.0
		III	211.6	12.7	23.6	2.8	traces	.
I	Ash + NPK	I	60.0	2.9	25.2	6.3	46.3	2.8
		II	28.7	5.8	19.0	3.8	139.6	28.0
		III	381.6	16.2	16.0	6.3	124.3	23.3

MIGRATION OF RADIUM THROUGH WATER AFTER 8-DAY CONTACT WITH ASH, IN PROPORTION 1 KG OF ASH + 2 dm^3 OF DISTILLED WATER

Table 27

	Description of sample	Test series	Ash from Power Plant Konin (from lignite)				Ash from Power Plant Halemba (from bituminous coal)			
			Sample designation	Sampling date	^{226}Ra from water (pCi/dm^3)	Standard deviation ±	Sample designation	Sampling date	^{226}Ra from water (pCi/dm^3)	Standard deviation ±
1	2	3	4	5	6	7	8	9	[illegible]	11
1.	Fresh ash from electrofilters	I	K-00	May 13,75	29,54	6,0	H-00	Sep.9,76	15,08	2,9
2.	Ash from sedimentation basin	I	K-01	May 13,75	24,30	5,8	H-01	Jun. 6,75	5,96	2,0
		II					H-01	Sep.29,75	27,61	5,6
		III					H-01	Sep. 9,76	11,65	5,7
3.	Ash from treatment plots of 0 series	I	0	May 13,75	23,85	5,6	0	Jun. 6,75	11,93	2,8
		II	0	Sep. 25,75	25,49	5,2	0	Sep. 29,75	16,77	3,4
		III	0	Sep. 6,76	10,31	6,3	0	Sep. 9,76	27,68	3,6
4.	Ash from treatment plots of A series (20 cm layer of soil + NPK)	I	A	May 13, 75	14,91	4,0	A	Jun. 6, 75	6,56	2,3
		II	A	Sep 25, 75	62,11	12,6	A	Sep. 29,75	9,12	1,6
		III	A	Sep. 6, 76	7,97	13,3	A	Sep. 9, 76	88,98	6,3

The ash samples lack manganese on other than the plots fertilized with soil (table 34). Zinc occurs in excess- especially on plots covered with soil. The soil contained from 90 to 122 ppm Zn. It is possible that the excess quantity of Zn contributed to a decrease in crops on plots covered with soil.

The denotations of the sorption capacity of the formed soils (table 36) had shown a significant diversification, (the sum of basic cations from 0.13 to 48.11 mval/100 g of soil) whereby difficult is here to ascertain any regularity. It appears, that the additions of fertile soil (combinations A,B,C) lowered the sorption capacity of the formed soils, probably because the sorptive capacity of ashes was higher than the sorptive capacity of the added fertile soil.

The participation of particular cations in the total of bases is also strongly differentiated and on the whole deviates very much from conditions obtaining in cultivated soils. And so on plots of D combination (bentonite added), E (low moor peat added) and F (addition of high moor peat) was found the content of 80-90 % of Mg^{++} with a low portion of Ca^{++}. In some samples collected from plots of C combination (added 5 cm layer of fertile soil), of D (added bentonite), of G (added farm manure), and of H (added N2PK) the content of K^{+} amounted to as much as 43 - 85 % of the total sum of bases, with the proportion of 3.2 - 4.1 % in pure ash (0 combination). Highest salinity was ascertained in some samples of C series (added 5 cm layer of fertile soil) and D series (added bentonite) coming to 10-38.9 percent of the total sorptive capacity.

Strong fluctuations in the sorptive capacity and in the ratio of: Mg^{++} : Ca^{++} : K^{+} : Na^{+} explain to a large extent the considerable variations in yield of vegetation and reflect on the non-uniformity of ashes under reclamation and on their chemical composition.

GRAIN SIZE DISTRIBUTION OF ASH TREATMENT PLOTS

HALEMBA

Table 28

Sample designation / Numbers of plots	Description of plots treatment	Fraction larger than 1.0 mm (%)	Percentage content of fractions (diameter in mm)								Pedological classification (polish)
			1-0,5	0,5-0,25	0,25-0,10	0,10-0,05	0,05-0,02	0,02-0,006	0,006-0,002	below 0,002	
1	2	3	4	5	6	7	8	9	10	11	12
	A. Materials used for treatments										
	Bentonite	8.0	13.2	40.4	24.4	4	4	4	4	6	light loamy sand
	Fertile soil	0.0	10.9	45.1	26.0	5	6	2	1	4	slightly loamy sand + peat
	B. Fresh ash										
	Fresh ash from electrofilters	0.0	0.2	1.8	9.0	26	33	22	5	2	plain dust
	Fresh ash from sedimentation basin	0.0	6.5	14.8	18.7	28	20	8	2	2	plain dust
	C. Ash under reclamation										
A	Ash + 20 cm layer of soil + NPK	0.7	11.4	28.9	24.7	10	14	3	3	5	light loamy sand+ + peat
B	Ash + 10 cm layer of soil + NPK	0.0	19.8	38.6	20.6	4	8	3	3	3	slightly loamy sand+ + peat
C	Ash + 5 cm layer of soil + NPK	0.0	18.5	32.5	23.0	10	7	3	2	4	- " -
D	Ash + bentonite + NPK	5.3	11.6	29.4	18.0	20	11	5	2	3	slightly loamy dusty sand
E	Ash + low bog peat + NPK	0.0	12.0	26.5	19.5	25	11	3	1	2	loose, dusty sand
F	Ash + mountain peat + NPK	0.0	15.0	33.7	16.3	23	7	2	1	2	- " -
G	Ash + ferm manure + NPK	1.3	17.5	29.3	20.2	22	6	2	1	2	- " -
H	Ash + N2PK	0.7	25.9	31.4	8.7	22	6	3	2	1	slightly loamy dusty sand
I	Ash + NPK	4.7	9.5	31.0	49.5	25	11	3	0	1	loose dusty sand
0	Ash without fertilfzation (control)	0.0	26.6	26.8	12.6	21	7	3	1	2	slightly loamy sand

GRAIN SIZE DISTRIBUTION OF ASH TREATMENT PLOTS KONIN

Table 29

Sample designation / Numbers of plots	Description of plot treatment	Fraction larger than 1,0 mm (%)	Percentage content of fractions (diameter in mm)								Pedological classification (polish)
			1-0,5	0,5 - 0,25	0,25- 0,10	0,10- 0,05	0,05- 0,02	0,02- 0,006	0,006- 0,002	below 0,002	
1	2	3	4	5	6	7	8	9	10	11	12
	A. Material used for treatments										
	Tertiary sand	1,7	12,2	44,0	33,0	5	1	2	1	1	loose sand
	Fertile soil	6,7	6,7	23,7	28,6	13	9	6	5	8	full loamy sand
	B. Fresh ash										
	Ash from electrofillers	0,0	0,8	4,1	15,1	23	49	1	1	6	plain dust
	Ash from sedimentation basin	0,0	2,8	19,4	39,8	21	5	5	3	4	light loamy sand
	C. Ash under reclamation										
A	Ash + 20 cm layer of soil + NPK	1,3	11,3	22,2	25,5	15	8	7	3	8	full loamy sand
B	Ash + 10 cm layer of soil + NPK	3,0	10,6	23,8	25,6	14	7	8	4	7	- " -
C	Ash + 5 cm layer of soil + NPK	3,0	11,2	27,7	24,1	15	7	7	3	5	light loamy sand
D	Ash + tertiary sand + NPK	0,0	14,0	36,9	28,1	10	4	4	1	2	slightly loamy sand
E	Ash + low bog peat + NPK	0,0	6,1	10,3	39,6	25	7	7	2	3	ash + peat
F	Ash + mountain peat + NPK	0,0	4,6	12,0	39,6	21	7	8	1	4	light loamy sand
G	Ash + farm manure + NPK	0,0	8,5	17,5	30,0	19	12	8	2	3	light loamy dusty sand
H(K)	Ash + green manure + N2PK	0,0	10,5	16,2	27,3	17	12	12	2	3	full loamy dusty sand
I	Ash + NPK	0,0	9,0	20,2	26,8	18	9	11	2	4	full loamy sand
0	Ash (control)	0,0	9,2	28,0	32,8	12	10	5	1	2	slightly loamy sand

PHYSICAL AND AQUEOUS PROPERTIES OF TREATED PLOTS
HALEMBA
(Date of sampling - Now. 18, 1976)

Table 30

Sample designation Numbers of plots	Description of plot treatment	Seed mixture	Depth sample (cm)	Density weight in g/cm^3		General porosity %	Water capacity % of volume	
				weight density	bulk density		capillary	field
1	2	3	4	5	6	7	8	9
A-2	Ash + 20 cm layer of soil + NPK	2	0-10	2.54	0.88	65.4	49.2	
A-3	- " -	3	0-10	2.55	0.99	61.1	49.8	21.2
A-4	- " -	4	0-10	2.56	0.93	63.7	48.1	
B-2	Ash + 10 cm layer of soil + NPK	2	0-10	2.44	0.67	72.5	46.4	
B-3	- " -	3	0-10	2.40	0.91	62.0	50.5	19.0
B-4	- " -	4	0-10	2.42	0.77	70.6	52.1	
C-2	Ash + 5 cm layer of soil + NPK	2	0-10	2.41	0.91	62.4	52.6	
C-3	- " -	3	0-10	2.35	0.82	60.8	55.4	20.3
C-4	- " -	4	0-10	2.40	0.93	61.2	53.9	
D-1	Ash + bentonite + NPK	1	0-10	2.46	0.92	62.6	47.9	
D-2	- " -	2	0-10	2.43	0.89	63.8	52.5	
D-3	- " -	3	0-10	2.34	0.87	62.8	51.7	22.1
E-1	Ash + low bog peat + NPK	1	0-10	2.29	0.73	68.1	58.3	
E-2	- " -	2	0-10	2.30	0.76	66.9	57.6	
E-3	- " -	3	0-10	2.32	0.71	69.4	55.8	26.7
F-1	Ash + mountain peat + NPK	1	0-10	2.33	0.73	68.9	52.0	
F-2	- " -	2	0-10	2.36	0.78	66.9	52.2	
F-3	- " -	3	0-10	2.40	0.81	66.2	57.6	24.3
G-1	Ash + farm manure + NPK	1	0-10	2.44	0.82	66.4	54.6	
G-2	- " -	2	0-10	2.51	0.85	66.1	56.3	
G-3	- " -	3	0-10	2.50	0.87	65.2	56.2	26.1
H-1	Ash + N2PK	1	0-10	2.33	0.77	66.9	57.5	
H-2	Ash + N2PK	2	0-10	2.31	0.75	67.5	52.0	
H-3	Ash + N2PK	3	0-10	2.29	0.74	67.6	57.3	31.6
I-1	Ash + NPK	1	0-10	2.50	0.97	61.2	51.9	
I-2	Ash + NPK	2	0-10	2.28	0.82	64.0	58.1	
I-3	Ash + NPK	3	0-10	2.22	0.78	64.5	60.2	29.2
• 0-1	Ash without fertilization (control)	1	0-10	2.46	0.81	67.1	56.9	
0-2	- " -	2	0-10	2.27	0.75	66.9	54.2	
0-3	- " -	3	0-10	2.26	0.65	72.1	60.1	23.0
			10-20	2.15	0.64	70.2	58.4	23.7
			20-30	2.32	0.67	75.9	53.7	24.8

PHYSICAL AND AQUEOUS PROPERTIES OF TREATED PLOTS

KONIN

(Date of sampling - Now. 11, 1976)

Table 31

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Depth sample (cm)	Density weight in g/cm^3		General porosity, %	Water capacity, % of volume	
				weight density	bulk density		capillary	field
1	2	3	4	5	6	7	8	9
A-2	Ash + 20 cm layer of fertile soil + NPK	2	0-10	2.65	1.40	47.2	30.3	14.0
A-3	- " -	3	0-10	2.68	1.47	45.1	26.4	16.7
A-4	- " -	4	0-10	2.64	1.48	43.8	29.5	
B-2	Ash + 10 cm layer of fertile soil + NPK	2	0-10	2.68	1.41	47.4	31.6	
B-3	- " -	3	0-10	2.62	1.43	45.4	28.1	20.3
B-4	- " -	4	0-10	2.69	1.35	49.8	30.8	
C-2	Ash + 5 cm layer of fertile soil + NPK	2	0-10	2.65	1.31	50.5	33.7	
C-3	- " -	3	0-10	2.63	1.22	53.6	41.8	17.3
C-4	- " -	4	0-10	2.71	1.12	58.6	43.9	
D-1	Ash + tertiary sand + NPK	1	0-10	2.72	1.01	62.8	37.8	
D-2	- " -	2	0-10	2.70	0.88	67.4	41.9	
D-3	- " -	3	0-10	2.59	1.22	59.9	34.7	19.2
E-1	Ash + low moor peat + NPK	1	0-10					
E-2	- " -	2	0-10					
E-3	- " -	3	0-10					
F-1	Ash + mountain peat + NPK	1	0-10	2.71	0.65	76.0	56.2	
F-2	- " -	2	0-10	2.56	0.68	73.8	55.9	
F-3	- " -	3	0-10	2.60	0.74	71.5	54.1	
G-1	Ash + farm manure + NPK	1	0-10	2.72	0.75	72.4	53.6	
G-2	- " -	2	0-10	2.58	0.68	74.2	54.4	
G-3	- " -	3	0-10	2.62	0.74	71.7	52.7	
H(K)-1	Ash + green maize manure + + N2PK	1	0-10	2.31	0.75	67.5	54.1	
H(K)-2	- " -	2	0-10	2.72	0.61	77.5	55.7	
H(K)-3	- " -	3	0-10	2.55	0.68	73.3	52.9	
I-1	Ash + NPK	1	0-10	2.59	0.61	76.4	55.6	
I-2	Ash + NPK	2	0-10	2.72	0.56	79.4	55.9	
I-3	Ash + NPK	3	0-10	2.61	0.57	78.1	58.0	
0-1	Ash without fertilization (control)	1	0-10	2.64	0.74	71.9	54.1	
0-2	- " -	2	0-10	2.70	0.71	73.7	56.3	
0-3	- " -	3	0-10	2.66	0.63	76.3	58.2	
			10-20	2.63	0.60	77.2	56.0	
			20-30	2.98	0.54	79.0	54.9	

Konin (tables 33, 35 and 37)

The pH of fresh ash from Konin ranges from 12.6 to 12.7 (table 33). The ash in the disposal areas is reduced to between 9.2 to pH 10.9. The ash in the treatment plots had pH´s from 7.6 to 8.8.

Fresh ash from the precipitators shows only 7.93 % of calcium carbonate (table 33) despite the presence of 27.94 - 34.13 % of CaO (table 19). On fresh disposal stack the content of $CaCO_2$ varied up to 17.29 percent.

Fresh ash from the precipitators contained 0.16 to 0.32 percent organic carbon. In samples taken from plots being reclaimed the C reserve ranged up to 4.85 percent (table 34), and was generally correlated with increases in $CaCO_3$. In samples of plots treated with fertile soils and organic materials the C content was as high as 0.92 percent, which can be explained by the addition of humus treatment and by root growth.

Ash from the precipitaters did not contain assimilable forms of phosphorus, magnesium, manganese and zinc (tables 34 and 35). In the process of hydraulic sluicing, manganese did become available. Phosphorus concentrations were low even with fertilization.

Fresh ash contained 8-10 ppm of water-soluble boron (table 35). Samples of ash from the still-wet disposal area contained 19 to 29 ppm of boron, and samples from plots contaiwed as much as 37.5 ppm. Large amounts of this microelement could cause negative effects on plants at the early stages of growth. Relatively low amounts of boron were measured in plots covered with thick layers of soil where the soil serves as insulation.

The sorptive properties of produced soils are here even more diversified than in Halemba (table 37). The total of bases amounts from 14.12 mval/100 g (D combination with added tertiary sand), to 99.59 mval/100 g (combination with added high moor peat). Pure ash on the control combination plots is characterized by a high sorption capacity within limits of the 40-52 mval/100 g, which seldom happens in Poland in cultivated soils. This results probably from a considerable portion of silty substance of a montmorillonite origin. Further increase in this capacity was accomplished through additions of low moor peats (52-57 mval) of high moor peats, (55-59 mval), of farm manure (72-82 mval), and of green mulch (to 67 mval). Addition of mineral soil in combinations A, B and C lowered the total of bases to about the 16-19 mval/100 g. The proportion of particular cations in the total quantity of bases is also strongly diversified. And so the participation of Mg^{++} in the total sorption complex fluctuates from 7.5 % (A-3 combination with addition of 20 cm layer of fertile soil), to 92.3 % (G-3 combination with added farm manure), and the proportion of Ca^{++} fluctuates from 5.3 % (G-3 combination with farm manure), to 90.4 % (combination A-3 with addition of 20 cm of fertile soil). The proportion of K^{+} is relatively small in the total high sorption capacity (0.6 - 3.3 %), similarly is the proportion of Na^{+} (0.7 - 3.4 %). Pure ash from control plot (0 combination) has a composition of cations similar to the fertile soil used to fertile combinations A, B and C.

SALINITY

In order to ascertain the levels of salt in the ashes, the sodium chloride concentrations were measured. Concentrations of over 9 g/dm^3 were measured for fresh ash (or 1.67 % NaCl). Soils containing more than 1 % NaCl are considered saline in Poland. In the presence of $CaCO_3$, NaCl will be changed to NaOH and will thereby result in an increase in alkalinity.

Salinity was measured by calculating the quantity of salts dissolved in water (by the method of Sturway in Nowosielski modification) through measurement of electrical conductivity with a conductance bridge (Hungarian manufacture) of AK 102/1 type - and converting it to Na Cl content per dm^3 of the measured substance.

Results of the sodium chloride measurements are presented in table 38 the ashes of bituminous coal contained relatively less soluble salts than those from lignite ash. Hydraulic sluicing caused a reduction in

ANALYSIS OF CHANGES IN CHEMISTRY OF TREATED ASH WITH TIME

HALEMBA

I series of tests - samples taken on the Jun. 9, 1975
V series of tests - samples taken on the Sep. 5, 1977

Table 32

Sample designation Numbers of plots plots)	Description of plot treatment	pH reaction in KCl		P_2O_5 content in mg/100g (after Egner)		K_2O content in mg/100g (after Egner)		Mg content in mg/100 g		0 gen. content in %		$CaCO_3$ content in %	
		Series of tests											
		I	V	I	V	I	V	I	V	I	V	I	V
1	2	3	4	5	6	7	8	9	10	11	12	13	14
A-2	Ash + 20 cm layer of soil + NPK	6.0	5.6 4.4	11.8	2.9 1.3	11.5	1.5 3.0	x/ a 15.0	7.8 11.0	5.19	3.15 3.62	0.33	0.33 0.33
A-3	- " -	4.2	5.4 4.2	4.6	1.4 1.3	6.5	1.5 2.5	a 15.0	8.9 10.6	9.67	. 4.85	0.16	0.25 0.33
A-4	- " -	6.4	5.6 6.4	22.0	3.8 16.5	16.5	2.0 4.0	a 15.0	13.0 26.5	5.16	3.91 5.08	0.25	0.25 0.42
B-2	Ash + 10 cm layer of soil + NPK	5.2	5.8 5.3	7.8	5.8 2.3	17.5	2.5 3.0	a 15.0	21.0 30.0	2.61	. 8.19	0.16	0.33 0.42
B-3	- " -	5.8	4.7 5.5	16.5	5.0 6.0	17.4	2.5 2.5	a 15.0	12.2 32.0	13.85	5.73 9.18	0.33	0.25 0.42
B-4	- " -	5.6	7.7 6.8	12.5	13.6 16.5	20.5	4.0 4.0	a 15.0	38.0 23.0	13.77	. 5.03	0.25	0.42 0.59
C-2	Ash + 5 cm layer of soil + NPK	5.9	8.1 7.3	14.0	18.3 19.1	18.0	5.0 5.5	a 15.0	30.0 15.5	5.64	3.51 4.59	0.16	2.54 1.35
C-3	- " -	6.7	8.3 7.7	25.0	13.2 18.3	19.0	5.0 6.0	a 15.0	68.5 23.0	5.46	3.45 3.56	0.76	4.32 2.80
C-4	- " -	7.1	9.6 8.2	35.0	7.0 19.1	20.0	7.5 5.5	a 15.0	46.0 27.0	5.17	1.57 2.92	1.26	7.42 3.13
D-1	Ash + bentonite + NPK	8.2	9.5 8.1	75.0	14.0 21.0	36.0	7.5 10.0	a 15.0	44.0 30.0	2.97	1.40 1.69	2.28	6.15 3.98
D-2	- " -	8.4	8.8 8.6	64.0	25.0 16.5	43.0	8.5 9.5	a 15.0	33.5 33.5	2.70	2.86 1.72	2.09	. 4.41
D-3	- " -	8.6	8.9 8.7	59.0	18.3 18.3	29.0	6.5 12.5	a 15.0	29.5 44.0	2.64	3.15 1.75	3.72	3.90 5.60
E-1	Ash + low bog peat + + NPK	8.1	8.0 8.3	88.5	22.9 105.0	23.5	6.0 6.0	a 15.0	12.0 11.0	4.74	5.67 5.32	1.77	1.27 1.78
E-2	- " -	8.2	8.4 8.4	56.0	21.0 25.0	20.0	6.0 8.0	a 15.0	19.5 13.8	6.38	5.85 5.49	2.29	1.69 1.95
E-3	- " -	8.0	8.4 8.6	56.0	20.0 22.9	18.0	6.5 7.0	a 15.0	27.0 12.7	6.37	4.56 4.56	2.71	3.39 2.29
F-1	Ash + mountain peat + + NPK	8.5	8.5 8.4	54.4	24.0 14.0	16.0	7.5 6.5	a 15.0	18.5 13.4	5.06	4.32 6.08	3.22	2.63 1.86
F-2	- " -	8.6	8.7 8.8	53.0	20.0 18.3	15.0	8.0 8.0	a 15.0	33.5 36.5	4.90	2.86 3.62	3.98	4.45 7.42
F-3	- " -	8.7	8.8 8.9	37.5	17.7 21.0	13.5	7.5 7.5	a 15.0	44.0 24.5	3.60	3.48 3.10	4.39	5.51 4.87
G-1	Ash + farm manure + + NPK	8.7	8.8 8.8	36.5	16.5 24.0	20.5	7.5 7.5	a 15.0	40.0 21.5	2.46	2.80 .	6.08	6.15 4.32

Table 32 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14
G-2	Ash + farm manure + + NPK	8.8	8.8 8.7	19.1	17.7 59.0	24.0	6.0 7.5	a 15.0	42.5 19.5	2.73	2.57 3.15	6.08	6.57 3.60
G-3	– " –	8.7	8.6 8.9	41.5	30.0 18.3	30.0	6.5 11.0	a 15.0	24.5 35.0	3.15	3.86 3.30	4.05	3.13 5.09
H-1	Ash + N2PK	8.5	8.6 8.8	75.0	24.0 22.9	30.0	8.0 8.5	a 15.0	19.5 24.5	4.37	3.56 3.04	3.13	1.48 4.66
H-2	– " –	8.5	8.2 8.7	57.5	22.9 22.0	22.5	8.0 8.0	a 15.0	13.1 12.3	4.05	4.32 .	1.94	2.12 1.78
H-3	– " –	8.5	8.6 8.6	72.5	20.0 25.0	22.0	7.0 7.5	a 15.0	23.0 11.8	3.54	2.92 3.97	2.11	3.47 2.54
I-1	Ash + NPK	8.8	8.9 8.8	43.0	22.9 15.0	18.5	5.5 7.5	a 15.0	32.0 36.5	2.40	2.69 1.34	3.31	5.17 6.87
I-2	– " –	8.7	8.8 8.8	46.0	20.0 22.0	22.0	8.5 6.0	a 15.0	35.0 30.0	2.52	3.42 1.34	4.90	3.47 5.94
I-3	– " –	8.7	8.7 8.9	31.0	22.9 20.0	15.0	5.5 12.0	a 15.0	22.5 47.0	2.61	4.27 2.36	6.08	2.96 3.47
0-1	Ash without fertilization (control)	8.7	8.6 8.6	43.0	22.9 22.9	12.0	5.0 5.0	a 15.0	21.5 25.0	4.05	4.03 3.27	3.89	4.07 6.36
0-2	– " –	8.7	8.6 8.5	51.5	22.0 24.0	12.5	19.5 7.0	a 15.0	20.0 11.6	4.57	3.86 .	4.07	2.33 2.12
0-3	– " –	8.6	8.6 8.5	48.5	20.0 25.0	10.5	7.5 7.0	a 15.0	19.5 11.6	4.80	4.32 4.27	4.05	2.12 2.03
H-00	Fresh ash from electrofilters	12.0		80.0		25.0		a 15.0		4.41		0.50	

x/ a = above

ANALYSIS OF CHANGES IN CHEMISTRY OF TREATED ASH WITH TIME

KONIN

I series of tests - samples taken on the Jun. 12, 75
II series of tests - samples taken on the Sep. 8, 1977

Table 33

Sample designation / Numbers of plots	Description of plot treatment	pH reaction in KCl		P_2O_5 content in mg/100 g (after Egner)		K_2O content in mg/100 g (after Egner)		Mg content in mg/100$^{x/}$		C gen. content in %		$CaCO_3$ content in %	
		Series of tests											
		I	V	I	V	I	V	I	V	I	V	I	V
1	2	3	4	5	6	7	8	9	10	11	12	13	14
A-2	Ash + 20 cm layer of soil + NPK	7.7	8.1 8.3	13.2	11.8 9.0	9.5	2.5 2.5	6.0	6.2 8.9	0.81	0.92 0.78	1.01	1.10 1.86
A-3	- " -	7.8	8.0 8.1	12.5	16.0 15.5	7.5	3.0 3.0	7.2	7.3 10.0	0.81	0.93 0.80	1.01	1.18 1.65
A-4	- " -	7.7	8.1 8.1	17.7	21.0 18.3	9.5	6.5 4.5	7.6	10.9 11.0	0.87	0.90 0.80	1.43	1.52 1.86
B-2	Ash + 10 cm layer of soil + NPK	8.2	8.0 8.4	20.0	16.0 16.5	10.0	3.5 3.0	9.1	8.9 20.0	0.81	0.78 0.83	1.69	1.18 3.10
B-3	- " -	7.6	8.5 8.4	11.8	19.1 12.5	7.5	4.5 3.0	7.1	21.5 14.9	0.87	0.92 0.83	1.26	5.30 2.89
B-4	- " -	8.0	8.3 8.2	19.1	9.7 12.5	12.0	4.0 3.5	7.8	11.6 9.2	0.78	0.89 0.81	1.18	1.95 2.07
C-2	Ash + 5 cm layer of soil + NPK	8.2	8.4 8.3	17.7	14.5 13.2	8.5	3.5 8.5	10.2	20.0 9.7	0.74	0.87 0.86	1.18	3.60 2.27
C-3	- " -	8.3	8.4 8.5	11.2	14.0 10.0	12.5	3.5 3.5	13.3	19.5 21.5	0.76	0.89 0.99	1.86	4.66 4.76
C-4	- " -	8.4	8.5 8.1	16.0	5.6 12.5	22.5	4.0 4.5	13.7	30.5 9.3	0.71	0.92 0.84	1.01	15.93 1.86
D-1	Ash + tertiary sand + NPK	8.5	8.7 7.7	12.2	16.0 6.4	11.0	3.0 1.0	a 15	19.0 11.4	0.90	0.90 1.60	1.16	4.55 1.24
D-2	- " -	8.5	8.5 8.4	8.0	8.8 11.8	14.0	3.0 3.0	a 15	26.0 13.4	1.04	1.36 1.33	4.05	9.31 2.89
D-3	- " -	8.8	8.6 8.4	7.8	7.5 8.6	20.0	2.5 1.0	a 15	20.0 7.8	1.09	1.27 0.92	4.39	6.62 1.44
E-1	Ash + low bog peat + + NPK	8.6	8.5 8.7	5.6	5.4 2.5	26.0	12.5 9.5	a 15	35.0 72.0	1.86	2.01 2.21	13.93	16.56 20.22
E-2	- " -	8.5	8.8 8.6	0.7	1.4 2.0	29.5	6.0 8.5	a 15	79.0 84.0	1.57	1.88 2.33	12.00	17.18 17.72
E-3	- " -	8.6	8.6 8.6	1.9	3.8 2.9	28.0	7.0 9.5	a 15	41.0 53.5	1.84	2.19 2.04	12.00	16.76 19.60
F-1	Ash + mountain peat + + NPK	8.5	8.6 8.4	1.7	3.4 3.2	35.5	12.5 10.0	a 15	67.0 49.5	1.88	2.61 2.28	12.00	15.93 16.05
F-2	- " -	8.7	8.6 8.6	1.0	3.2 3.6	18.5	9.0 8.5	a 15	61.5 39.0	1.56	2.33 1.47	13.08	18.42 10.76
F-3	- " -	8.6	8.6 8.5	1.[illegible]	3.6 3.4	31.0	8.0 10.0	a 15	50.0 64.5	2.03	2.47 2.43	14.58	15.52 18.63

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a = above

Table 33 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14
G-1	Ash + farm manure + + NPK	8,8	8,6 8,5	0,7	2,9 6,4	55,0	17,5 20,5	a 15	53,0 40,0	1.77	2.37 2.55	15.22	15.52 19.04
G-2	- " -	8,5	8,7 8,6	0,7	2,0 2,3	40,0	7,5 6,0	a 15	71,5 75,0	1.90	1,57 4,85	17.37	15.73 18.63
G-3	- " -	8,6	8,7 8,4	1,0	2,5 6,4	62,0	9,5 20,5	a 15	62,0 39,0	1.79	1.97 1.76	15.22	12,83 17.80
H(K)-1	Ash + green manure + N2PK	8,6	8,5 8,4	0,6	5,0 5,4	24,0	11,5 24,0	a 15	46,5 55,0	1.56	1.81 2.36	16.51	16.76 19.25
H(K)-2	- " -	8,7	8.5 8,6	0,7	6,2 1,8	20,0	17,0 10,5	a 15	60,5 83,0	2,00	1,41 2,95	16,72	13,24 22,35
H(K)-3	- " -	8,7	8,5 8,4	0,6	7,3 4,0	25,5	21,5 15,0	a 15	56,0 80,0	2,01	2,07 1,85	17.37	14,69 16,97
I-1	Ash + NPK	8,7	8,6 8,4	1,0	3,4 5,6	33,0	19,0 12,5	a 15	55,0 58,5	1,95	2.12 2.73	16.29	17.18 25.46
I-2	- " -	8,7	8,6 8,6	1,2	2,0 2,7	26,0	9,5 10,0	a 15	64,5 80,0	1,90	2,07 1,98	14,15	17,80 23,18
I-3	- " -	8,8	8,5 8,5	0,3	3,2 3,2	20,5	14,5 17,5	a 15	42,0 53,0	1,60	2,15 2,13	14,15	21,32 21,73
0-1	Ash without fertilization (control)	8,5	8,6 8,6	1,6	3,6 4,0	33,0	11,0 10,0	a 15	38,0 36,5	1,11	1,30 1,29	5,75	13,66 14,49
0-2	- " -	8,6	8,8 8,6	1,2	1,6 2,3	32,5	5,5 6,0	a 15	64,0 48,5	1,46	1,54 1,12	7,07	19,45 13,24
0-3	- " -	8,8	8,5 8,4	0,5	2,7 5,2	20,0	19,0 21,5	a 15	55,0 38,0	1,81	2,00 2,00	17,79	18,00 21,94
	Fresh ash from electro-filters	12,0	.	0,0	.	12,5	.	1,2	.	0,32	.	7,93	.

x/ a = above

salts. Treatment with salts, sand, and manure likewise reduced the salinity an additional drop in salinity was measured over the 3-year period of the experiment.

The ashes of lignite are more strongly saline. The salinity is also reduced by hydraulic sluicing and treatment. Treatments of lignite ash showed that the salinity of the mixture is inversely proportional to the thickness of fertile soil layer (a dilution effect).

As in the case of bituminous ash, the salinity of lignite ashes further decreased during the period of the experiment.

Of the plots planted with trees and bushes, the lowest salinity occurred on those treated with soil. Observations of salinity on the remaining plots provide no noticeable differences.

After the 3 year cultivation of grasses and papilionaceous vegetation the highest salinity level was ascertained in samples taken from the experimental field in Konin, in particularly from plots of the H combination, (addition in the first year of cultivation of double dose of mineral fertilizers, and in the following year of green mulch of corn) - to 3.45 g of NaCl in a 1 dm^3 of the dry soil mass.

The ash from control plot contained 2.5 - 3.1 g of NaCl. Least saline were samples taken from plots of the A combination (addition of fertile soil - 20 cm layer), containing 0.18 - 0.30 g of $NaCl/dm^3$ of soil. As nonsaline can be considered the plots of combinations:

- A (layer of 20 cm of fertile soil + NPK)
- B (layer of 10 cm of fertile soil + NPK)
- C (layer of 5 cm of fertile soil + NPK)

and the plots of the D combination (addition of tertiary sand + NPK during the 1975-76 period) not treated in 1977 with mineral fertilizers.

Samples taken from the experimental field in Halemba in 1977 indicate salinity from 0.09 to 0.75 g of $NaCl/dm^3$ of soil, therefore can be considered as freed from salt in the effect of three yearly cycle of performed reclamation. Fresh ash from the electrofilters contained about 5.1 g NaCl (table 38).

POLLUTION OF WATERS

Methodology

The objective of the investigations described below was the determination of composition and of amounts of substances which could be leached from ashes with water. Opportunities for such leaching exist during hydraulic sluicing to the disposal area and as a result of infiltration of precipitation.

The tests were carried out on samples of:

a) fresh ashes collected from the electrostatic precipitators,

b) fresh ashes collected from surfaces freshly drained of water in the disposal area,

c) mixtures of ashes and amendments, collected from the various experimental plots.

Samples were collected from the treatment plots every year in order to observe the dynamics of weathering processes and the effect of prolonged contact of the water with the ash.

Five kg samples were placed in polyethylene containers and saturated with distilled water in gravimetric ratio of 1:2 (10 dm^3 of water). The water remained in contact with the samples for eight days. Changes in the dissolved solids concentrations were monitored through electrical conductivity measurements. After 8 days the water was decanted and chemical analysis performed. The results of sodium chloride calculations were presented in table 38. Tables 39 and 40 contain specific conductance data for the analyzed samples. Specific chemical analyses performed on water extracts are summarized in tables 41 and 42.

ANALYSIS OF CHANGES IN TRACE ELEMENT CONTENT OF TREATED ASHES WITH TIME - HALEMBA

I test series - samples taken on Jun. 9,75
V test series - samples taken on Sep. 5,77

Table 34

Sample designation Numbers of plots	Description of plot treatment	Content of microelements in ppm									
		B		Cu		Mn		Mo		Zn	
		Test series									
		I	V	I	V	I	V	I	V	I	V
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm layer of soil + NPK	0,8	0,30 0,30	4,2	2,3 2,8	29,5	19,0 32,0	0,09	0,04 0,04	95,0	46,6 23,2
A-3	- " -	0,6	0,28 0,27	4,2	2,3 4,4	52,5	8,0 38,0	0,07	0,05 0,03	102,5	24,8 20,4
A-4	- " -	1,4	0,40 0,54	9,0	1,8 3,6	54,0	12,0 17,0	0,21	0,07 0,07	197,5	25,6 50,0
B-2	Ash + 10 cm layer of soil + NPK	1,5	0,36 0,69	7,0	3,1 12,2	64,0	21,0 14,0	0,16	0,07 0,08	235,0	50,0 50,0
B-3	- " -	1,7	0,39 0,80	7,8	10,6 3,8	50,0	3,0 30,0	0,16	0,12 0,13	245,0	7,3 50,0
B-4	- " -	1,8	0,65 0,60	7,8	4,7 2,6	58,0	3,0 10,0	0,13	0,17 0,10	225,0	50,0 50,0
C-2	Ash + 5 cm layer of soil + NPK K	1,5	0,56 0,69	8,6	9,5 15,0	45,0	0,0 7,0	0,13	0,13 0,13	245,0	40,5 23,2
C-3	- " -	1,3	0,77 0,61	11,8	11,8 15,0	41,0	0,0 5,0	0,16	0,26 0,15	235,0	18,2 27,1
C-4	- " -	1,3	0,80 0,65	12,5	14,4 8,9	13,0	0,0 0,0	0,19	0,18 0,12	180,0	19,6 0,0
D-1	Ash + bentonite + NPK	1,3	1,80 0,56	12,5	19,4 10,5	0,5	0,0 2,0	0,23	0,29 0,14	31,0	0,0 8,8
D-2	- " -	1,2	1,00 0,52	13,2	26,0 16,7	0,0	0,0 0,0	0,20	0,18 0,13	22,0	0,0 10,3
D-3	- " -	1,4	0,72 0,71	15,8	25,0 17,0	0,0	0,0 0,0	0,33	0,26 0,14	12,0	7,1 0,0
E-1	Ash + low bog peat + + NPK	1,5	0,67 0,74	14,8	15,0 12,4	0,0	0,0 0,0	0,32	0,16 0,18	45,0	11,4 16,8
E-2	- " -	1,4	0,74 0,66	14,8	15,0 13,0	0,0	0,0 0,0	0,26	0,12 0,14	37,0	8,9 16,0
E-3	- " -	1,5	0,74 0,68	14,4	12,4 12,4	0,0	1,0 0,0	0,27	0,16 0,16	50,0	6,5 2,4
F-1	Ash + mountain peat + + NPK	1,4	0,58 0,59	16,2	14,2 14,5	0,0	2,0 0,0	0,29	0,18 0,13	21,5	2,4 2,0
F-2	- " -	1,1	0,83 1,68	17,3	15,6 12,2	0,0	0,0 0,0	0,20	0,17 0,18	19,5	0,0 1,8
F-3	- " -	1,3	0,81 0,77	19,8	14,6 14,6	0,0	0,0 0,0	0,25	0,16 0,16	3,8	0,0 0,3
G-1	Ash + farm manure + + NPK	1,6	0,83 0,68	18,8	13,4 16,1	0,0	0,0 0,0	0,28	0,13 0,22	1,6	0,0 2,4
G-2	- " -	1,6	0,67 0,60	18,8	13,0 17,2	0,0	0,0 0,0	0,30	0,13 0,16	0,7	2,8 3,2

Table 34 continuation

1	2	3	4	5	6	7	8	9	10	11	12
G-3	Ash + farm manure + + N2PK	1,6	0,43 0,74	15,0	15,2 14,2	0,0	0,0	0,25	0,10 0,14	[illegible]	[illegible] [illegible]
H-1	Ash + N2PK	1,3	0,08 0,64	16,2	15,0 14,6	0,0	0,0 0,0	0,36	[illegible] 0,12	14,0	[illegible] [illegible]
H-2	– " –	0,8	0,31 0,90	16,6	8,9 14,2	0,0	0,0 3,0	0,24	0,16 0,17	[illegible]	13,2 [illegible]
H-3	– " –	0,8	0,53 0,46	13,1	11,2 15,2	0,0	0,0 [illegible]	0,34	0,10 0,17	23,0	[illegible] [illegible]
I-1	Ash + NPK	1,4	1,22 0,09	18,8	18,5 20,0	0,0	0,0 0,0	0,28	0,26 [illegible]	[illegible]	[illegible] [illegible]
I-2	– " –	1,2	2,00 0,76	18,0	14,4 15,8	0,0	0,0 0,0	0,38	[illegible] [illegible]	1,0	[illegible] [illegible]
I-3	– " –	1,2	1,34 1,48	19,8	11,6 12,8	0,0	0,0 0,0	0,30	[illegible] 0,14	[illegible]	[illegible] [illegible]
0-1	Ash without fertilization (control)	1,2	0,75 0,90	15,8	8,6 8,6	0,0	0,0 0,0	0,29	0,20 0,22	11,0	[illegible] [illegible]
0-2	– " –	0,9	0,82 0,60	15,5	8,4 13,1	0,0	0,0 0,0	0,26	0,11 [illegible]	17,0	[illegible] [illegible]
0-3	– " –	1,5	0,66 0,62	20,0	9,4 13,1	0,0	0,0 0,0	0,29	0,25 0,16	[illegible]	[illegible] [illegible]
H-00	Fresh ash from electrofilters	9,2	0,62	27,6	.	1,0	.	[illegible]	.	13,8	.
H-01	Fresh ash from sedimentation pond	15,0	.	15,0	.	0,0	.	[illegible]	.	17,0	.

ANALYSIS OF CHANGES IN TRACE ELEMENT CONTENT OF TREATED ASHES WITH TIME - KONIN

I test series - samples taken on the Jun. 12,75

V test series - samples taken on the Sep. 8,77

Table 35

Sample designation / Numbers of plots	Description of plot treatment	Microelement content in ppm									
		B		Cu		Mn		Mo		Zn	
		Test series									
		I	V	I	V	I	V	I	V	I	V
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm layer of soil + NPK	0,6	0,8 12,0	2,1	2,9	13,0	14,0 12,0	0,08	0,05 0,03	9,7	7,2
A-3	- " -	0,9	0,7 0,8	2,1	2,5	9,0	10,0 14,0	0,04	0,05 0,03	6,8	7,1
A-4	- " -	0,9	2,4 1,6	2,1	3,3	11,0	0,0 12,0	0,05	0,10 0,38	6,5	6,4
B-2	Ash + 10 cm layer of soil + NPK	3,5	2,4 4,5	2,1	2,75	3,0	2,0 4,0	0,09	0,06 0,06	5,0	6,4
B-3	- " -	0,7	7,5 1,7	4,5	3,0	9,0	11,0 6,0	0,04	0,12 0,07	7,4	6,6
B-4	- " -	2,2	2,9 1,0	2,1	2,75	5,5	0,0 13,0	0,52	0,06 0,03	6,8	6,2
C-2	Ash + 5 cm layer of soil + NPK	5,0	6,5 1,7	2,5	2,75	1,0	0,0 15,0	0,05	0,09 0,03	5,5	7,8
C-3	- " -	4,0	3,5 4,5	2,5	4,95	1,0	0,0 4,0	0,08	0,07 0,08	5,4	0,3
C-4	- " -	5,0	12,5 0,8	2,5	3,50	1,0	0,0 16,0	0,07	0,13 0,02	7,0	2,7
D-1	Ash + tertiary sand + + NPK	6,0	6,0 0,9	1,1	0,75	2,0	2,0 11,0	0,07	0,08 0,00	1,4	1,6
D-2	- " -	19,5	15,5 4,5	4,8	1,75	1,0	0,0 6,0	0,23	0,14 0,05	0,5	1,1
D-3	- " -	26,5	11,5 3,0	3,8	1,25	2,0	0,0 4,0	0,20	0,05 0,01	0,5	2,2
E-1	Ash + low bog peat + + NPK	25,0	15,0 16,5	0,0	0,25	3,0	0,0 0,0	0,21	0,07 0,07	0,3	1,0
E-2	- " -	28,8	22,5 21,5	0,3	1,0	4,0	0,0 0,0	0,21	0,13 0,08	0,1	0,6
E-3	- " -	28,6	26,5 18,0	0,3	0,75	3,0	0,0 0,0	0,20	0,12 0,11	0,3	0,2
F-1	Ash + mountain peat + + NPK	29,5	21,3 23,5	0,3	0,2	3,0	0,0 0,0	0,21	0,13 0,10	0,3	0,9
F-2	- " -	33,5	17,5 16,0	0,0	0,3	3,0	0,0 0,0	0,24	0,16 0,13	0,2	0,4
F-3	- " -	29,3	4,0 20,0	0,0	0,55	3,0	1,0 0,0	0,24	0,16 0,13	0,3	0,5
G-1	Ash + farm manure + + NPK	29,3	20,5 20,5	0,0	0,05	2,0	1,0 0,0	0,26	0,16 0,10	0,2	0,5
G-2	- -	36,3	25,5 22,0	0,0	1,0	4,0	3,0 0,0	0,19	0,19 0,12	0,3	0,3
G-3	- " -	37,5	25,5 17,0	0,0	0,55	3,0	0,0 0,0	0,29	0,18 0,18	0,2	0,4

Table 35 continuation

1	2	3	4	5	6	7	8	9	10	11	12
H(K)-1	Ash + green manure + NPK	29,5	19,0 21,5	0,0	0,2	3,0	2,0 1,0	0,27	0,17 0,16	0,6	0,4
H(K)-2	– " –	33,5	20,5 25,5	0,0	0,75	6,5	0,0 0,0	0,25	0,19 0,19	0,2	0,2
H(K)-3	– " –	33,5	9,0 26,0	0,0	0,3	2,0	0,0 2,0	0,27	0,21 0,19	0,3	0,3
I-1	Ash + NPK	28,7	21,5 .	0,0	0,55	2,0	3,0 0,0	0,32	0,16 0,16	0,2	0,3
I-2	– " –	27,0	16,5 26,5	0,0	0,05	1,5	0,0 2,0	0,28	0,19 0,16	0,3	0,4
I-3	– " –	28,7	19,0 21,5	0,0	0,05	2,0	2,0 4,0	0,29	0,19 0,16	0,2	0,4
0-1	Ash without fertilization (control)	25,0	18,5 16,0	5,2	3,55	2,0	0,0 0,0	0,21	0,14 0,12	0,5	0,8
0-2	– " –	26,5	28,0 21,5	4,8	2,0	2,0	0,0 0,0	0,27	0,16 0,17	0,5	0,4
0-3	– " –	27,5	17,5 19,5	0,0	0,05	3,0	2,0 0,0	0,25	0,22 0,18	0,3	0,4
K-00	Fresh ash from electrofilters	8,0	.	0,0	.	0,0	.	0,38	.	0,0	.
K-01	Fresh ash from sedimentation pond	19,5	.	4,8	.	0,0	.	0,24	.	0,0	.

SORPTIVE CAPACITY OF SOILS FORMED FROM ASHES IN HALEMBA

(samples taken on Sep. 9, 76)

Table 36

Sample designation Numbers of plots	Description of plot treatment	Seed mixture	Content of basic cations (mval/100 g of soil)					Proportion of cations (per cents)			
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Total S	$\frac{Mg^{++}}{S}$	$\frac{Ca^{++}}{S}$	$\frac{K^{+}}{S}$	$\frac{Na^{+}}{S}$
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm of soil + NPK	2	1,03	9,88	0,43	0,73	12,07	8,5	81,9	3,6	6,0
A-3	- " -	3	1,44	14,06	0,55	0,23	16,28	8,8	86,4	3,4	1,4
A-4	- " -	4	1,23	9,66	0,59	0,25	11.73	10,5	82,4	5,0	2,1
B-2	Ash + 10 cm of soil + NPK	2	1,44	9,66	0,33	0,20	11,63	12,4	83.1	2,8	1,7
B-3	- " -	3	1,44	11,42	0,45	0,26	13.57	10,6	84.2	3,3	1,9
B-4	- " -	4	1,64	9,44	0,38	0,21	11.67	14,1	80,9	3,2	1,8
C-2	Ash + 5 cm of soil + NPK	2	1,85	12,08	21,08	4,20	39,21	4,7	30,8	53.8	10,7
C-3	- " -	3	1,23	10,10	0,84	2,77	14,94	8,2	67,6	5,7	18,5
C-4	- " -	4	2,26	16,69	18,79	5,83	43,57	5,2	38,3	43,1	13,4
D-1	Ash + bentonite + NPK	1	4,53	14,50	3,22	4,11	26,36	17,2	55,0	12,2	15,6
D-2	- " -	2	1,03	14,93	0,56	10,52	27,04	3,8	55,2	2,1	38,9
D-3	- " -	3	2,06	16,25	23,78	6,02	48,11	4,3	33,8	49,4	12,5
E-1	Ash + low bog peat + NPK	1	9,47	0,43	0,51	0,23	10,64	89,0	4,0	4,8	2,2
E-2	- " -	2	10,51	6,37	19,87	4,59	41,34	25,4	15,4	48,1	11,1
E-3	- " -	3	10,09	0,43	0,33	0,20	11,05	91,3	3,9	3,0	1,8
F-1	Ash + mountain peat + NPK	1	9.10	0,43	0,43	0,18	10,14	89,8	4,2	4,2	1,8
F-2	- " -	2	9,06	1,53	0,31	0,25	11,15	81,3	13,7	2,8	2,2
F-3	- " -	3	11,33	0.87	0,61	0,95	13,76	82,3	6,3	4,5	6,9

Table 36 continuation

1	2	3	4	5	6	7	8	9	10	11	12
G-1	Ash + farm manure + NPK	1	0,61	8,78	9,98	2,00	21,37	2,9	41,1	46,7	9,3
G-2	– " –	2	1,23	11,86	0,59	1,40	15,08	8,2	78,6	3,9	9,3
G-3	– " –	3	traces	traces	0,12	0,02	0,14	0,0	0,0	85,7	14,3
H-1	Ash + N2PK	1	0,61	10,76	0,28	0,66	12,31	5,0	87,4	2,3	5,3
H-2	– " –	2	0,82	13,78	0,28	0,24	14,52	5,6	90,8	1,9	1,7
H-3	– " –	3	traces	traces	0,11	0,02	0,13	0,0	0,0	84,6	15,4
I-1	Ash + NPK	1	3,70	14,28	1,93	3,92	23,83	15,5	59,9	8,1	16,4
I-2	– " –	2	2,88	9,00	0,42	0,25	12,55	22,9	71,7	3,3	2,1
I-3	– " –	3	1,03	10,75	0,20	0,22	12,21	8,4	88,2	1,6	1,8
0-1	Ash without fertilization - control	1	2,26	12,30	0,53	0,22	15,31	14,8	80,3	3,5	1,4
0-2	– " –	2	2,88	17,35	0,67	0,33	21,23	13,6	81,7	3,2	1,5
0-3	– " –	3	3,70	15,37	0,84	0,35	20,26	18,3	75,9	4,1	1,7

Reference to col. 3:

1 – mixture of lucerne with white melilot
2 – mixture of grasses
3 – mixture of lucerne with orchard grass
4 – white melilot

Changes in properties of ashes in the process of hydraulic sluicing as represented by analyses of leachate

Halemba

The electrical conductivity of ash sampled at Halemba decreased by a factor of 17.5 in the process of hydraulic sluicing to the disposal area (table 41). This confirms the hypothesis that significant leaching took place during hydraulic transportation. The highest specific conduction value measured occurred in ash after 8 hours contact (3.9 mS), then the conductance decreased, indicating that complex chemical processes take place in the ash disposal area.

Chemical analysis of water extracts collected after 8 - day contact time (table 41) shows the ash has generally high hardness (23.2 mval) and a high chemical oxygen demand (52.0 mg 0_2). In the process of hydraulic stacking these concentrations decrease to 5.4 mval and 9.2 mg0 respectively. The degree of leaching is indicated by the high dissolved solids concentration (751 mg/dm^3- sum of pos. 17, 18, table 41). The ashes collected from the newer portions of the disposal area contain only 116 mg/dm^3 of dissolved substances and thus show the effects of leaching during hydraulic transport from the power plant.

Konin

The electrical conductivity of ash sampled at Konin was reduced from 14.6 mS to 0.7 mS during the process of hydraulic sluicing to the disposal area (table 42). It must be emphasized that the electrical conductivity changed with increased contact time in a different manner for ash samples than it did for samples of treated ash from the experimental plots. Namely the conductance decreased with increased contact time for the ash samples while conductivity in the remaining samples of water extracts increased systematically. On the basis of these results it is concluded that the ash is strongly leached during initial contact with water. Subsequently the dissolved solids are converted as is indicated by the measurements of other chemical parameters and hardness (table 42) shown below:

- total hardness 319 mval in fresh ash decreases to 14 mval in ash in the disposal area
- content of dissolved solids decreases from 5 734 mg/kg to 278 mg/kg.

Noteable among the soluble substances contained in fresh ash are Ca (1815 mg/kg of ash), magnesium (282.4 mg/kg), sulphates (970 mg/kg), and boron (4.54 mg/kg). In samples of ash collected from the disposal area basin the content of these substances decreases considerably (see table 42).

Changes in properties of ash treated with soil amendments as represented by analysis of leachates

Halemba

The electrical conductivity of leachates of treated ash did not exceed 0.706 mS (table 39). Thus the salinity level is low.

Other chemical analyses of water extracts show relatively small changes caused by the ash treatments, because, as described this was expected since the concentration in the ash in the disposal area were quite low to begin with. The bentonite treatment did produce a relatively large amount of sodium in the leachate.

Konin

The electrical conductivity of water extracts from treated ash remained about as low as measured for untreated ash collected from the disposal area (table 40).

The pH of water extracts from treated ash showed a relative decrease for ash treatments of manure and soil, but showed a slight increase in the case of ash which had been fertilized (only).

From the data presented in table 42, it is apparent that the nitrate,

SORPTIVE CAPACITY OF SOILS FORME SHES IN KONIN

(Samples taken on Sep.)

Table 37

Sample designation Numbers of plots	Description of plot treatment	Seed mixture	Content of basic cations (mval/100 g of soil)					Pr. Proportion of cations (percents)			
			Mg^{++}	Ca^{++}	K^{+}	Na^{+}	Total. S	$\frac{Mg^{++}}{S}$	$\frac{Ca^{++}}{S}$	$\frac{K^{+}}{S}$	$\frac{Na^{+}}{S}$
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm of soil + NPK	2	1.72	13.96	0.54	0.14	16.36	10.5	85.3	3.3	0.9
A-3	- " -	3	1.37	16.50	0.23	0.16	18.26	7.5	90.4	1.2	0.9
A-4	- " -	4	2.23	14.91	0.25	0.13	17.52	12.7	85.1	1.5	0.7
B-2	Ash + 10 cm of soil + NPK	2	2.23	15.87	0.26	0.19	18.55	12.0	85.6	1.4	1.0
B-3	- " -	3	2.58	13.64	0.28	0.15	16.65	15.5	81.9	1.7	0.9
B-4	- " -	4	2.92	16.18	0.27	0.18	19.55	14.9	82.8	1.4	0.9
C-2	Ash + 5 cm. of soil + NPK	2	3.27	13.64	0.51	0.17	17.59	18.6	77.5	2.9	1.0
C-3	- " -	3	3.96	32.69	0.51	0.33	37.49	10.6	87.2	1.4	0.8
C-4	- " -	4	3.27	19.67	0.36	0.22	23.52	13.9	83.6	1.6	0.9
D-1	Ash + tertiary sand + NPK	1	2.15	17.61	0.19	0.13	20.08	10.7	87.7	0.9	0.7
D-2	- " -	2	1.54	12.37	0.09	0.12	14.12	10.9	87.6	0.6	0.9
D-3	- " -	3	2.23	19.36	0.11	0.12	21.90	10.2	88.4	0.5	0.9
E-1	Ash + low bog peat + NPK	1	34.44	15.87	0.84	1.01	52.16	66.0	30.4	1.6	2.0
E-2	- " -	2	35.64	19.67	0.97	1.21	57.49	62.0	34.2	1.7	2.1
E-3	- " -	3	43.91	6.66	1.12	1.26	52.95	82.9	12.6	2.1	2.4
F-1	Ash + mountain peat + NPK	1	49.76	23.17	1.29	0.57	74.79	66.5	31.0	1.7	0.8
F-2	- " -	2	39.95	13.64	1.04	1.23	55.86	71.5	24.4	1.9	2.2
F-3	- " -	3	72.67	25.07	0.80	1.05	99.59	73.0	25.2	0.8	1.0

Table 37 continuation

1	2	3	4	5	6	7	8	9	10	11	12
G-1	Ash + farm manure + NPK	1	56.65	22.35	0.84	1.46	81.80	69.3	27.9	1.0	1.8
G-2	- " -	2	44.77	27.29	0.67	0.66	73.39	61.0	37.2	0.9	0.9
G-3	- " -	3	66.81	3.80	0.90	0.86	72.37	92.3	5.3	1.2	1.2
H(K)-1	Ash + green manure + N2PK	1	31.68	33.96	0.78	1.14	67.56	46.9	50.3	1.1	1.7
H(K)-1	- " -	2	25.83	6.98	0.72	1.15	34.68	74.4	20.1	2.1	3.4
H(K)-1	- " -	3	29.10	17.45	0.75	1.22	48.52	60.0	36.0	1.5	2.5
I-1	Ash + NPK	1	7.74	43.80	0.87	1.27	53.68	14.4	81.6	1.6	2.4
I-2	- " -	2	4.82	43.16	0.94	1.28	50.20	9.6	86.0	1.9	2.5
I-3	- " -	3	8.95	45.07	0.90	1.34	56.26	15.9	80.1	1.6	2.4
0-1	Ash without fertilization - control	1	5.16	46.02	0.58	0.62	52.38	9.9	87.9	1.1	1.1
0-2	- " -	2	6.02	33.32	0.49	0.81	40.64	14.8	82.0	1.2	2.0
0-3	- " -	3	7.92	35.86	0.90	1.49	46.17	17.2	17.7	1.9	3.2

Reference to col 3:

1 - saintoin
2 - mixture of grasses
3 - mixture of lucerne with orchard grass
4 - white melilot

ammonia and organic nitrogen content (of water extracts) generally increased for the treated ash. On the other hand, the chloride and sulphate concentrations were lower than in the fresh ash. Note worthy is the large increase in sodium for those plots treated only with fertilizers.

Changes in properties of water extracts after -3years reclamation

Halemba

Samples of the treated plots were again collected in September, 1977, or 27 months after the first collection (table 41). Relative to the results of analyses of water extracts from the first samples, the second samples showed increases in levels of ammonia, nitrates and organic nitrogen, and decreases in boron and zinc. The amount of dissolved solids decreased in plots of A series, while the samples of the other series were characterized with increases. The chemical oxygen demand increased on all series while the biological oxygen chemical increased on all but the B and I series plots. From these analyses it is concluded that: (1) there are relatively small amounts of soluble salts in the bituminous coal ashes, (2) the treatments cause only small changes in the character of the leachate, (3) there is a relatively small probability of surface and ground water contamination through contact with the bituminous ashes studied, especially if the ash is disposed of in a dryer climate.

Konin

The treatment plots at Konin were reassessed in Sep. of 1977. These analyses indicated a larger change in water - soluble elements than did the reanalyses performed on Halemba samples. Content of dissolved solid was particularly large in the second set of samples taken from plots treated with peat, with farm manure and with fertilizers. The dissolved solids concentrations were relatively low in water extracts from samples of plots treated with soil.

Samples collected after 3 year reclamation period produced highly mineralized water extracts (table 42) mainly due to large contents of calcium, of nitrates, organic nitrogen, magnesium, sulphates (45 to 2266 mg SO_4) of sodium and potassium.

The soluble salts were decreased by treatment with soils, peat or manure. This is reflected in the improved response of plants during the later stages of the revegetation experiment.

In view of the high concentrations of soluble substances in the Konin ash, pollution of surface or ground waters may take place when in contact with these ashes.

BIOLOGICAL ACTIVITY OF TREATED ASH

During the first ten days of September 1977 samples of soil were taken from a depth of 5-10 cm from all treatment plots seeded with seed mixture No. 3 and from G and 0 series plots seeded with plant mixtures No. 1 and 2; for laboratory control purposes, a sample of ash was washed with water of a neutral pH.

Designations of rank and activity of basic groups of microorganisms and of enzyme activity were performed using the methods described in section 6.

Comparison of the results indicates greater biological activity in ashes derived from lignite, this was also evident in the greenhouse experiments.

Halemba

The highest activity occurred on those plots wherelow moor and high moor peats were added(sec. E-3, F-3 - tables 43 and 44). Plots treated with farm manure (G), also showed greater biological activity in comparison with control samples. The addition of soils to ash did not increase the activity to the degree expected. In fact, additions of

SALINITY CHECK OF SOILS UNDER RECLAMATION

Table 38

Sample designation / Numbers of plots	Description plot treatment	Seed mixture	Halemba			Konin		
			Na Cl g/dm^3					
			I Jun.9,75	II Aug.30, 76	III Sep.5, 77	I Jun.12, 75	II Sep.7, 76	III Sep.8, 77
1	2	3	4	5	6	7	8	9
A-2	Ash + 20 cm layer of soil + NPK	mixture 2	0,57	0,15	0,18 0,12	1,38	0,51	0,18 0,27
A-3	- " -	" 3	0,57	0,09	0,09 0,09	0,81	0,24	0,18 [illegible]
A-4	- " -	" 4	0,78	0,09	0,12 0,27	0,87	0,24	0,27 0,30
B-2	Ash + 10 cm layer of soil + NPK	" 2	0,87	0,15	0,12 0,21	1,62	0,18	0, 0,81
B-3	- " -	" 3	0,78	0,15	0,12 0,30	0,75	0,33	0,60 0,81
B-4	- " -	" 4	0,93	0,24	0,12 0,42	1,29	1,62	0,81 0,30
C-2	Ash + 5 cm layer of soil + NPK	" 2	0,78	0,18	0,42 0,42	2,43	0,54	0,60 0,24
C-3	- " -	" 3	0,78	0,12	0,48 0,36	2,34	2,73	0,51 0,60
C-4	- " -	" 4	1,02	0,09	0,51 0,39	3,06	1,68	1,62 0,33
D-1	Ash + bentonite + NPK	" 1	0,66	0,12	0,75 0,27			
D-2	- " -	" 2	0,66	0,12	0,51 0,33			
D-3	- " -	" 3	0,63	0,15	0,39 0,33			
D-1	Ash + tertiary sand + NPK	" 1				1,86	1,05	0,90 0,60
D-2	- " -	" 2				2,73	0,66	2,13
D-3	- " -	" 3				2,91	1,14	1,83 0,33
E-1	Ash + low bog peat + NPK	" 1	0,45	0,15	0,24 0,27	3,21	3,42	2,46 2,58
E-2	- " -	" 2	0,39	0,21	0,33 0,27	3,21	3,21	3,39 2,94
E-3	- " -	" 3	0,45	0,15	0,30 0,30	3,22	3,66	2,58 3,09
F-1	Ash + mountain peat + NPK	" 1	0,39	0,15	0,36 0,24	2,58	3,57	2,67 2,73
F-2	- " -	" 2	0,30	0,18	0,42 0,39	3,21	3,21	3,00 2,58
F-3	- " -	" 3	0,45	[illegible]	0,45 0,33	3,54	3,36	2,73 3,00
G-1	Ash + farm manure + NPK	" 1	0,45	0,18	0,45 0,36	3,06	3,21	3,00 2,73

Table 38 continuation

1	2	3	4	5	6	7	8	9
G-2	Ash + farm manure + NPK	mixture 2	0,51	0,24	0,39 0,27	3,78	3,21	2,88 3,30
G-3	- " -	" 3	0,57	0,18	0,36 0,39	3,96	3,36	2,73 2,88
H(K)-1	Ash + green manure + N2PK	" 1	0,51	0,15	0,33 0,33	3,21	4,20	2,88 3,45
H(K)-2	- " -	" 2	0,45	0,12	0,24 0,30	3,21	3,90	3,30 3,39
H(K)-3	- " -	" 3	0,57	0,15	0,30 0,27	3,69	4,32	2,88 3,30
I-1	Ash + NPK	" 1	0,45	0,18	0,39 0,39	3,21	3,72	3,09 3,21
I-2	- " -	" 2	0,45	0,15	0,33 0,39	2,73	2,94	3,00 3,15
I-3	- " -	" 3	0,57	0,21	0,33 0,39	3,30	3,66	3,30 3,21
0-1	Ash without fertilization (control)	" 1	0,36	0,15	0,30 0,33	3,00	2,82	2,46 2,58
0-2	- " -	" 2	0,30	0,27	0,30 0,27	2,67	3,00	3,06 2,64
0-3	- " -	" 3	0,36	0,21	0,30 0,24	3,63	3,15	2,67 2,88
	Ash from electrofilters		5,10			9		
	Ash from fresh disposal		0,78			1,62		
	Tertiary sand					0,12		
	Bentonite		1,41					
	Mountain peat		0,33			0,36		
	Low moor peat		0,24			0,71		
	Fertile soil		0,32			0,32		

Notice: III series of samples taken on Sep. 5, 77 (Halemba) and on Sep. 8, 77 (Konin) concern plots fertilized in 1977 (the upper line), and the not fertilized plots (lower line).

bentonite resulted in higher activity than did soil treatments.

Greater activity was measured for plots treated with single doses of NPK than was achieved with double doses.

The addition of soil induced a mass development of fungi (table 43). Large colonies of actinomyces were found. This development favors alkaline reaction in the medium.

The complete lack of algae and the lack of measurable effects after vaccination with Chlorella vulgaris algae indicates the toxicity of these treated ash soils towards this group of organisms. Lack of azoto bacteria in all samples also indicates unfavourable fertility conditions and a poor medium for biological activity. Even treatment with soil was not conducive to development of these bacteria.

The microbiological investigations show the presence of Clostridium, spirillum and other bacteria (short bacilli, very active), especially in mountain peat (F-3), and bentonite (D-3) (table 44). One would assume that the further development of this group of bacteria is hampered by adverse reaction "soils" analyzed. Nitrifying bacteria require development conditions which are absent in the ash. Only average quantities of nitrates were identified which indicates the lack of nitrifying processes. One can ascertain the minimal but advantageous effect of mountain peat (F-3) and of seeding with a mixture of lucerne and orchard grass (no. 3 seed mix.). In this last case the results approximate a level of activity similar to that obtained with soils.

Partial denitrification (table 44) leading to reduction of nitrates to nitrites in a microbiological manner involving aerobic and anaerobic microbes occurred on treatment plots fertilized with farm manure and seeded with the mixture of lucerne and orchard grass (G-3). Treatment with mountain peat and with bentonite (F-3 and D-3) also encouraged this process.

Cellulose was most actively decomposed on plots treated with farm manure (G-3); with bentonite (D-3) and with mountain peat (F-3). The results were better for peat and bentonite than for treatments with soil.

The activity of saccharose correlates, in general, with the organic content of the soil, hence the highest values were obtained for plots treated with soil (table 44). The addition of low bog peat (E-3) and farm manure (G-3) also increased saccharose activity.

Konin

Conditions of soil environment for biological activity in lignite ash were better than those of bituminous ash hence the treatments of the ash did not produce significant differences in activity.

Greatest activity of microorganisms was measured for plots fertilized with farm manure (G), and especially on ones seeded with mixture No 3, table 43. High activity was also found where soil (A, B, C), and tertiary sand (D) were used. Alfalfa (0-1, 0-3) encouraged development of microbes. Comparing the results of fungi rank measurements conducted on soil extracts and on selected nutrients of Martin, a large number developed on plots with increased phosphoric fertilization (H-3), on plots with mineral fertilization only (I-3), and where tertiary sand was added (D-3).

The actinomyces rank values indicate better development conditions on plots fertilized with soil (A-3, B-3, C-3), with farm manure (G), and with low bog peat (E-3).

The presence of algae on the lignite ash indicates much greater biological activity in comparison with bituminous ashes from Halemba. A particularly large development of algae was noted on plots treated with peat (E-3 and F-3). In other treatments, the lack of organic matter constrained the occurrence of algae.

The azotobacter introduced to the soil was sustained and enhanced in the lignite ash treatments which should reflect the better chemical and physical conditions. One could probably successfully innoculate with azotobacter chroococcum.

Microorganisms fixing atmospheric nitrogen were successfully developed on plots treated with soil (A, B,C) low bog peat (E) and farm

SPECIFIC ELECTRIC CONDUCTIVITY OF WATER CONTACTING ASHES FROM POWER PLANT HALEMBA

I test series - samples taken on Jun. 6, 75

III test series - samples taken on Sep. 9, 77

Table 39

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Specific el. conductivity (in uS$^{x/}$) - contact time in hours									
			2	4	6	8	24	48	72	120	144	192
1	2	3	4	5	6	7	8	9	10	11	12	13
H-00	Fresh ash from electrofilters	I	1395	3208	3720	3952	3813	3552	3236	2650	2371	2185
H-01	Fresh ash from sedimentation pond	I	81	103	117	144	206	272	274	309	311	330
0	Ash without fertilization (control)	I III	67 175	117 176	130 216	135 270	163 307	195 318	203 335	227 363	230 381	246 395
A	Ash + 20 cm layer of soil + NPK	I III	158 116	177 158	196 193	209 203	237 216	274 216	269 214	276 221	272 206	279 228
B	Ash + 10 cm layer of soil + NPK	I III	177 125	209 226	260 279	339 325	409 386	502 395	502 411	529 390	502 423	520 450
C	Ash + 5 cm layer of soil 5 NPK	I III	232 183	283 332	325 446	381 493	446 586	576 604	585 623	627 623	627 651	669 670
D	Ash + bentonite + NPK	I III	297 162	302 228	335 272	353 291	393 358	483 381	483 400	529 409	529 428	567 440
E	Ash + low bog peat + NPK	I III	260 137	302 195	343 214	372 232	418 284	488 302	488 325	529 339	529 361	557 375
F	Ash + mountain peat + NPK	I III	35 123	98 181	159 214	186 232	253 283	322 305	329 325	376 342	376 363	408 375
G	Ash + farm manure + NPK	I III	167 135	172 167	195 190	209 209	260 270	325 297	333 321	365 348	369 363	395 370
H	Ash + N2PK	I III	279 115	279 156	288 181	307 205	381 240	446 260	446 285	520 309	529 335	580 345
I	Ash + NPK	I III	167 161	241 271	297 330	353 353	455 418	584 451	595 493	668 507	669 539	706 554

x/ $1\ u S = 1.10^{-3}\ mS = 1.10^{-6}\ S$ (Simens)

$1\ S = 1 : Ohm = 1\ m^{-2} . kg^{-1} S^{3} A^{2}$.

SPECIFIC ELECTRIC CONDUCTIVITY OF WATER CONTACTING ASHES FROM POWER PLANT KONIN

I series of tests - samples taken on May 13, 75

III series of tests - samples taken on Sep. 7, 77

Table 40

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Specific el. conductivity (in uS^{-1}) - control time in hours									
			2	4	6	8	24	48	72	120	144	192
1	2	3	4	5	6	7	8	9	10	11	12	13
K-00	Fresh ash from electrofilters	I	9672	9486	9300	9114	8556	8184	7988	7626	7440	7254
K-01	Fresh ash from sedimentation pond	I	330	600	650	730	892	1090	1130	1190	1190	1227
K-A	Ash + 20 cm layer soil + NPK	I	214	232	232	251	288	349	363	400	400	427
		III	60	85	114	124	153	167	190	223	256	260
K-B	Ash + 10 cm layer of soil + NPK	I	325	335	409	362	442	614	668	726	752	780
		III	172	349	465	511	595	725	790	865	930	
K-C	Ash + 5 cm layer of soil + NPK	I	372	381	409	437	548	688	762	865	855	906
		III	293	469	604	669	800	828	874	948	976	990
K-D	Ash + tertiary sand + NPK	I	186	205	232	260	349	465	502	595	613	670
		III	228	372	456	502	679	697	753	818	893	910
K-E	Ash + low bog peat + NPK	I	465	483	540	603	717	902	913	1020	1020	1070
		III	800	1093	1274	1395	1683	1720	1765	1860	1934	1980
K-F	Ash + mountain peat + NPK	I	483	548	725	800	967	1210	1210	1375	1385	1440
		III	1162	1627	1813	1934	2046	2223	2278	2325	2371	2320
K-G	Ash + farm manure + NPK	I	744	818	950	1070	1283	1490	1620	1720	1675	1720
		III	976	1433	1655	1767	2046	2120	2167	2213	2278	2350
K-H	Ash + N2PK	I	309	474	558	716	883	1134	1140	1140	1190	1273
		III	869	1346	1674	1927	2048	2278	2343	2408	2502	2530
K-I	Ash + NPK	I	762	1226	1466	1798	2015	2650	2790	2790	2830	2970
		III	362	1466	1627	1767	1979	2048	2139	2232	2232	2313
K-J	Ash without fertilization (control)	I	670	762	762	830	956	1098	1145	1220	1220	1373
		III	767	1237	1396	1581	1860	1860	2001	2092	2139	2269

Explanation: 1 µS = 1.10^{-3} mS = 1.10^{-6} S (Siemens)

1 S = 1 1/ohm [illegible]

CHEMICAL ANALYSIS OF WATER EXTRACTS AFTER 8-DAY CONTACT WITH ASHES FROM POWER PLANT HALEMBA (converted to 1 kg of dry mass of ash)

I test series - samples taken on Jun. 6, 75
III test series - samples taken on Sep. 9, 77

Table 41

	P a r a m e t e r		Test series	Content in samples collected from experimental plots and from electrofilters											
				H-00 fresh	H-01 fresh	0 plots 0 (control)	A (plots A ash + 20 cm layer of soil + NPK)	B (plots A ash + 10 cm layer of soil + NPK)	C (plots C ash + 5 cm layer of soil + NPK)	D (plots D ash + bentonite + NPK)	E (plots E ash + low bog peat + NPK)	F (plots F ash + mountain peat + NPK)	G (plots G ash + farm manure + NPK)	H (plots H ash + N2PK	I (plots I ash + NPK
1	2		3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Ammonia	- mg NH_4	I	0,30	0,02	0,06	4,00	1,34	0,14	0,18	0,06	0,06	0,16	0,32	1,26
			III			0,02	4,20	2,90	1,90	1,10	0,39	0,04	0,07	0,04	0,04
2.	Nitrates	- mg NO_3	I	0,32	0,20	1,76	0,00	0,00	10,00	3,80	4,00	0,48	1,80	7,72	3,86
			III			35,20	9,20	34,40	33,90	34,00	13,90	30,10	18,60	39,20	14,00
3.	Organic nitrogen	- mg Norg.	I	6,2	0,00	0,00	0,46	1,28	0,00	0,70	0,50	2,72	3,96	3,38	27,90
			III			11,80	13,40	8,40	0,00	6,30	7,20	7,70	0,00	7,70	3,30
4.	Phosphates	- mg PO_4	I	0,02	0,74	0,88	0,28	0,30	0,70	1,24	1,44	1,26	1,24	1,54	1,92
			III			1,69	0,11	0,06	0,31	0,07	0,65	1,76	1,70	1,89	0,53
5.	Calcium	- mg Ca	I	147,8	11,2	11,8	101,6	41,4	35,6	8,8	31,4	20,8	16,2	27,4	22,0
			III			57,1	29,6	78,6	71,1	93,2	54,5	51,9	44,1	49,4	44,2
6.	Magnesium	- mg Mg	I	10,9	16,4	57,1	97,0	30,0	27,8	12,2	19,7	19,4	19,4	26,0	20,6
			III			44,3	22,5	48,9	100,5	15,2	43,7	37,9	44,0	35,1	34,1
7.	Iron	- mg Fe	I	1,0	.	.	.	.	.	.	.	.	.	.	.
			III			1,0	3,5	3,1	1,2	0,9	1,2	1,1	1,0	1,1	1,0
8.	Chlorides	- mg Cl	I	22,5	2	2	10	14	[illegible]	8	26	6	8	20	18
			III			6	4	3	6	7	6	5	6	5	6
9.	Sulphates	- mg SO_4	I	61	28	10	54	108	4	12	32	44	22	34	62
			III			20	40	63	92	124	36	33	20	27	56
10.	Manganese	- mg Mn	I	0,2	.	.	.	.	.	.	.	.	.	.	.
			III			0,4	0,7	0,4	0,3	0,0	0,0	0,0	0,1	0,1	0,1
11.	Sodium	- mg Na	I	[illegible]	1,44	1,40	2,00	2,12	[illegible]	20,00	1,72	2,44	2,14	2,11	1,69
			III												
12.	Potassium	- mg K	I	30,41	0,01	0,66	4,58	7,24	7,50	11,94	8,00	5,26	6,34	15,14	8,44
			III			5,60	6,47	9,21	8,50	22,48	5,63	4,29	7,64	6,18	9,76

Table 41 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
13.	Lead - mg Pb	I III	0,040	0,060	0,000 0,028	0,016 0,026	0,043 0,026	0,033 0,064	0,014 0,026	0,011 0,027	0,012 0,028	0,015 0,028	0,018 0,028	0,000 0,028
14.	Copper - mg Cu	I III	0,0095	0,0022	0,001 0,027	0,004 0,012	0,012 0,019	0,009 0,017	0,001 0,063	0,001 0,028	0,032 0,023	0,003 0,003	0,002 0,021	0,001 0,021
15.	Zinc - mg Zn	I III	0,023	0,386	0,546 0,010	0,702 0,947	0,282 0,033	0,136 0,033	0,036 0,060	0,134 0,016	0,266 0,010	0,200 0,015	0,106 0,059	0,346 0,011
16.	Boron - mg B	I III	0,853	0,704	0,586 0,060	0,658 0,048	0,728 0,086	0,524 0,116	0,760 0,012	0,350 0,088	0,328 0,088	0,690 0,059	0,506 0,028	0,482 0,123
17.	Dissolved solid substances - mg	I III	623	62	54 178	300 128	218 298	15[illegible] 341	162 306	162 205	108 181	82 180	128 156	184 254
18.	Dissolved volatile substances - mg	I III	128	34	36 239	134 150	226 247	156 363	68 186	68 165	44 191	74 186	102 187	98 267
19.	Total hardness - mval	I III	23,2	5,4	5,6 18,1	37,0 9,2	14,2 22,3	12,0 33,1	7,4 16,6	7,2 17,6	7,4 15,8	6,8 16,3	7,4 15,0	10,6 14,0
20.	Non-carbonate hardness - mval	I III	2,3	1,2	1,2 12,8	34,2 8,3	13,6 11,9	4,4 15,9	7,6 11,8	2,4 6,6	2,8 7,7	1,0 6,9	4,6 7,8	3,8 4,2
21.	B.O.D.5 - mg O_2	I III	1,0	0,2	1,2 5,0	8,6 31,2	29,0 6,5	5,0 13,8	5,6 4,2	1,6 6,2	1,0 5,4	0,2 6,6	0,2 1,5	3,6 7,0
22.	Permanganate oxygen consumption - mg O_2	I III	8,2	0,8	0,8 15,2	80,0 96,9	248,0 22,9	20,4 74,7	6,2 12,2	3,4 16,4	1,0 14,3	0,6 11,1	0,6 9,0	2,0 23,4
23.	C.O.D. - mg O_2	I III	52,0	9,2	21,0 84,0	235,6 364,0	75,6 257,1	6,0 303,0	31,4 91,0	34,4 111,0	25,4 102,0	21,0 154,0	22,6 74,0	23,8 163,0
24.	Cadmium - mg Cd	III	0,00154	0,00058	0,00088	0,00329	0,00150	0,00149	0,00085	0,00087	0,00056	0,00016	0,00059	0,00059
25.	Selenium - mg Se	III	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01

CHEMICAL ANALYSIS OF WATER EXTRACTS AFTER 8-DAY CONTACT WITH ASHES FROM POWER PLANT KONIN (converted to 1 kg of dry mass of ash)

I test series - samples taken on May 13, 75
III test series - samples taken on Sep. 7, 77

Table 42

	Parameter	Test series	Content of samples collected from experimental plots and from electrofilters											
			K-00 fresh ash from elec- trofil- ters	K-01 fresh ash from sedi- men- tation basin	0 (plots 0 ash without fertili- zation recla- mation (con- trol)	A (plots A ash + 20 cm layer of soil + NPK)	B (plots B ash + 10 cm layer of soil + NPK)	C (plots C ash + 5 cm layer of soil + NPK)	D (plots D ash + ter- tiary sand + NPK)	E (plots E ash + low bog peat + + NPK)	F (plots F ash + mo- untain peat + NPK)	G (plots G ash + farm manure + NPK)	H (plots H ash + N2PK)	I (plots I ash + NPK)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Ammonia - mg NH_4	I III	4.8	0.72	1.20 0.35	0.60 0.20	0.22 0.04	0.64 2.60	0.68 0.04	3.38 0.27	2.38 0.28	4.70 0.44	3.34 0.21	3.80 0.22
2.	Nitrates - mg NO_3	I III	0.32	0.30	4.16 35.50	6.88 0.16	6.96 0.15	4.34 0.65	4.70 3.22	3.38 27.21	6.56 36.30	0.36 5.50	2.94 213.30	2.66 0.50
3.	Organic nitrogen - mg Norg.	I III	0.00	0.00	0.68 6.10	0.30 5.70	0.12 8.30	0.00 0.00	1.40 4.20	2.76 8.40	2.16 31.30	2.70 0.00	2.84 32.10	2.66 6.80
4.	Phosphates - mg PO_4	I III	0.00	0.04	0.50 0.19	0.78 4.35	0.04 0.37	0.08 0.23	0.08 0.53	0.16 0.04	0.02 0.01	0.06 0.01	0.46 0.02	0.06 0.04
5.	Calcium - mg Ca	I III	1815.0	57.2	128.6 784.9	33.8 84.0	84.4 255.0	60.8 351.0	46.2 234.2	101.2 748.0	25.0 873.8	167.6 663.2	35.4 823.4	91.6 857.1
6.	Magnesium - mg Mg	I III	282.4	26.2	13.2 706.0	3.6 19.9	3.0 49.2	3.0 67.8	3.8 56.2	11.4 162.1	1.8 204.0	13.2 320.5	0.8 246.4	3.2 109.5
7.	Iron - mg Fe	I III	6.0	0.0	• 0.8	• 1.5	• 1.0	• 1.3	• 1.1	• 1.1	• 1.4	• 0.9	• 1.3	• 1.2
8.	Chlorides - mg C_1	I III	30	14	8 21.0	8 7.0	8 3.2	10 5.8	6 2.7	12 17.7	8 21.7	40 22.2	14 26.6	190 51.1
9.	Sulphates - mg SO_4	I III	970	188	322 1980	32 45	158 512	134 687	110 516	282 2040	60 2266	494 1919	122 2233	18 1773
10.	Manganese - mg Mn	III	traces •	• •	• traces	• traces	• 1.1	• 1.0	• 0.6	• 0.2	• traces	• traces	• traces	• traces
11.	Sodium - mg Na	I III	10.40	6.360	2.920 16.01	1.290 2.77	1.520 3.09	1.956 4.03	1.860 2.49	3.360 16.05	7.160 27.17	10.580 15.90	5.000 12.28	2.860 29.39

Table 42 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12.	Potassium - mg K	I	3,08	14,36	4,30	1,248	0,238	3,040	3,720	13,520	1,732	0,326	4,110	9,520
		III			16,28	3,13	4,50	9,01	3,91	19,63	32,29	20,98	16,58	26,52
13.	Lead - mg Pb	I	0,096	0,008	0,008	0,008	0,010	0,008	0,006	0,008	0,010	0,014	0,012	0,000
		III			0,054	0,008	0,059	0,091	0,093	0,076	0,132	0,096	0,118	0,120
14.	Copper - mg Cu	I	0,012	0,0024	0,001	0,005	0,0068	0,0052	0,0056	0,0002	0,0102	0,0104	0,0034	0,002
		III			0,011	0,018	0,029	0,011	0,057	0,051	0,014	0,035	0,020	0,023
15.	Zinc - mg Zn	I	0,038	0,382	0,126	0,112	0,116	0,088	0,174	0,190	0,203	0,177	0,169	0,476
		III			0,056	0,022	0,031	0,052	0,032	0,049	0,053	0,050	0,052	0,043
16.	Boron - mg B	I	4,540	0,696	0,624	0,494	0,260	0,380	0,396	0,394	0,356	0,352	0,294	0,730
		III			2,489	0,015	1,146	1,174	0,701	2,113	-	2,229	2,677	2,459
17.	Dissolved solid substances - mg	I	5,734	278	570	122	250	214	176	404	184	762	218	322
		III			3,097	187	920	1,341	840	2,685	3,321	2,709	3,414	3,097
18.	Dissolved volatile substances	I	246	40	78	88	132	54	56	94	60	108	54	78
		III			308	97	142	168	223	339	377	316	452	454
19.	Total hardness - mval/kg	I	319,2	14,0	20,8	6,0	12,6	9,2	7,2	16,8	4,0	26,6	5,0	13,6
		III			162,5	16,3	46,9	64,8	45,7	142,1	169,2	18,9	172,0	145,3
20.	Non-caronate hardness - mval/kg	I	138,0	3,8	18,0	4,0	8,8	4,8	3,0	12,4	-	20,6	-	-
		III			159,5	8,4	40,6	59,8	40,8	137,9	162,2	13,5	168,2	141,2
21.	B.O.D.5 - mgO_2	I	2,4	0,8	1,4	1,4	0,4	1,2	1,4	1,6	0,4	5,2	0,4	0,2
		III			1,3	4,3	2,6	1,9	30,0	8,4	7,3	3,8	3,4	1,9
22.	Permanganate oxygen consumption - mgO_2	I	4,8	10,4	3,6	6,0	11,0	8,4	16,4	11,4	10,0	25,6	3,6	5,2
		III			11,4	21,7	16,0	9,0	290,3	22,5	25,4	29,6	16,8	16,1
23.	C.O.D. - mg O_2	I	43,4	33,4	27,8	27,0	27,4	24,4	25,6	38,8	34,3	64,2	32,2	32,4
		III			38,0	86,0	81,0	78,0	636,0	60,0	117,0	111,0	5,0	65,0
24.	Cadmium - mg Cd	III	.	.	0,00152	0,00051	0,00171	0,00171	0,00251	0,00179	0,00433	0,00144	0,00173	0,00387
25.	Selenium - mg Se	III	.	.	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01

manure applied (G). Relatively large numbers of these microorganisms were found on plots, treated with mineral fertilizers (H, I).

Nitrification was weakest on plots with fertile soil (A, B, C) added.

The highest denitrification activity was measured in incubated material collected from plots treated with mountain peat (F-3) and with farm manure (G-1, G-3). Treatment with soil also increased denitrification activity but did so in an inverse relationship to the soil thickness.

The most active cellulose decomposition was found on plots treated with farm manure (G-1, G-2, G-3) and with peat (E,F). Mineral fertilization also favoured development of cellulolytic microflora.

The activity of saccharose was highest on plots treated with fertile soil (A, B, C) and on treatments with farm manure (G-3, G-2, G-1).

GROUND COVER OF EXPERIMENTAL PLOTS (tables 45 and 46)

The ground cover density of the experimental plots was measured using a modified phytosociological method. The measurements were made before gathering the second harvest in 1976 and in 1977. Results of these measurements for 1977 are presented in tables 45 and 46 as averages of measurements performed on 4 repetitions of each plot.

Comparison of the ground cover density measurements made at Halemba and Konin supports the following conclusions:

1. Better ground cover was achieved in Halemba than in Konin (81 versus 50 %).
2. Both in Halemba and in Konin seed mixture no. 3 (lucerne and orchard grass) gave the best ground cover. In Konin the ground cover with this mix averaged 69 percent. In Halemba the ccver was to 89 percent. The next highest ground cover density was obtained with seed mixture no. 2 (Konin - 60 percent, Halemba - 85 percent). White melilot provided a low 30 percent ground cover at Konin and 73 percent at Halemba.

3. Mixtures No 2 and No 3, which were sown on fertilized, cultivated objects, covered in Konin about 65 % of area, and in Halemba - 87 %. Poorest coverage with these mixtures took place in Konin, on plots fertilized with high, and low moor peats (E,F) and on control object (0), and weakest coverage of 68 % in Halemba was on object H-2, with double mineral fertilization.

4. Crown vetch (coronilla varia) in the seed No. 1 did not germinate, at Konin and the covering with sainfoin was generally not satisfactory. Especially on plots treated with peat, farm manure, and those plots without treatment. At Halemba, lucerne predominated at those plots seeded with mix No. 1 (particularly on plots treated with farm manure and with a double dose of fertilizer).

5. In mixture No. 2 orchard grass was strongest (the amount of seeds was 5 percent in the mixture, but after 3 years of cultivation it provided from 5 to 58 percent of the ground cover at Halemba and from 9 to 67 % at Konin). This grass grew aggressively on ash fertilized with soil, and on plots treated with tertiary sand at Konin (D-2), and with farm manure also at Konin (G-2). Other species such as white clover, tall rye grass, and annual meadowgrass provided minimal ground cover.

6. The No. 3 seed mix contained 86 percent lucerne and 14 percent orchard grass. However the ground cover consisted of from 39 to 95 percent orchard grass at Halemba and 4 to 84 percent orchard grass at Konin. The orchard grass grew particularly aggressively on plots treated with soil, with bentonite, and with tertiary sand. Ash treatments with peat, particularly peat from low moor, were not particularly suited for orchard grass.

7. White melilot did not grow well, particularly in Konin, where both the ash and the fertile soil were alkaline. Better results were obtained at Halemba on the plots treated with 10 and 5 cm thick layers of soil (B-4, C-4).

OCCURRENCE OF MICROORGANISMS IN PRODUCED ASH SOILS

Table 43

Sample designation	Description of plot treatment	Seed mixture	Microorganism occurence on extracts from ash (thousands to 1 g)							
			H a l e m b a				K o n i n			
Numbers of plots			bacteria	actino-myces	fungi	total number of micro-organisms	bacteria	actino-myces	fungi	total number of micro-organisms
1	2	3	4	5	6	7	8	9	10	11
A-3	Ash + 20 cm layer of soil + NPK	3	5510	3990	114	9614	3330	6300	54	9684
[illegible]	Ash + 10 cm layer of soil + NPK	3	5130	2660	190	7980	7000	10200	54	17254
C-3	Ash + 5 cm layer of soil + NPK	3	4860	2754	340	8154	5780	12580	170	18530
D-3	Ash + bentonite + NPK	3	6360	6510	57	12927				
-3	Ash + tertiary sand + NPK	3					3740	7700	220	11660
E-3	Ash + low bog peat + NPK	3	12600	6510	0	19110	7560	966	0	8526
F-3	Ash + mourtain peat + NPK	3	9960	3520	48	13528	828	1674	108	2610
G-1	Ash + farm manure + NPK	1	7890	5600	256	13696	2266	4620	440	7326
G-2	- " -	2	6650	1824	247	8721	9060	10600	120	19683
G-3	- " -	3	7524	3990	0	11454	4242	4200	140	8582
H-3	Ash + N2PK	3	4576	3360	0	7936				
H(K)-3	Ash + green manure + N2PK	3					54	1616	126	1796
I-3	Ash + NPK	3	6290	4420	102	10812	1140	6270	190	7600
0-1	Ash without fertilization (control)	1	3060	3780	0	6840	4200	630	220	5050
0-2	- " -	2	4080	1870	0	5950	510	561	0	2142
0-3	- " -	3	3281	3332	102	6715	3740	5661	170	9571
	Absolute control		0	0	0	0	0	0	0	0

Table 44

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Occurrence of microorganisms assimilating nitrogen in incubation soil, expressed with amount of consumed sugar in mg/g of ash		Nitrification activity in incubation soil 72 hrs, converted mg of NO_2^- to 100 g of ash		Denitrification activity in incubation soil 48 hrs, in mg NO_2^- converted to 100 g of ash		Cellulose decomposition in incubation soil in % of cellulose loss		Saccharose activity in mg of hydrolysed sugar in 24 hrs time per 100 g of ash	
			Halemba	Konin	Halemba	Konin	Halemba	Konin	Halemba	Konin	Halemba	Koran
1	2	3	4	5	6	7	8	9	10	11	12	13
A-3	Ash + 20 cm layer of soil + NPK	3	0,00	13,93	0,60	0,24	20	130	38,0	18,30	460	850
B-3	Ash + 10 cm layer of soil + NPK	3	2,56	14,95	0,52	0,03	80	170	34,3	12,70	390	500
C-3	Ash + 5 cm layer of soil + NPK	3	0,96	19,62	0,46	0,02	200	230	31,4	21,00	230	540
D-3	Ash + bentonite + NPK	3	10,02		0,36		280		70,0		96	
D-3	Ash + tertiary sand + NPK	3		3,37		0,54		0		2,70		20
E-3	Ash + low bog peat + NPK	3	3,20	8,71	0,49	0,52	20	0	62,2	45,90	156	4
F-3	Ash + mountain peat + NPK	3	10,98	0,00	0,60	0,30	210	480	41,9	37,50	96	24
G-1	Ash + farm manure + NPK	1	8,64	6,50	0,15	0,42	150	250	34,0	54,70	53	52
G-2	" " "	2	3,20	0,50	0,22	0,66	60	100	59,0	61,80	90	68
G-3	" " "	3	6,40	1,92	0,54	0,33	410	280	79,3	76,80	140	84
H-3	Ash + N2PK	3	6,40		0,27		60		49,0		120	
H(K)-3	Ash + green manure + N2PK	3		7,18		0,72		0		49,30		100
I-3	Ash + NPK	3	8,96	15,00	0,14	0,39	100	110	52,3	32,40	117	8
0-1	Ash without fertilization (control)	1	8,00	0,00	0,17	0,54	20	0	19,0	7,89	40	12
0-2	" " "	2	8,96	4,30	0,25	0,67	20	100	2,7	36,00	85	12
0-3	" " "	3	6,72	5,30	0,66	0,27	90	200	5,7	18,80	140	12
	Absolute control		0	0	0	0	0	200	0	0	40	0

GROUND COVER OF EXPERIMENTAL PLOTS BY PLANT SPECIES IN PERCENTS

Halemba - prior to II swath 1977

Table 45a

Treatment series	A			B			C			D			E		
Seed mixture / Plant species	2	3	4	2	3	4	2	3	4	1	2	3	1	2	3
Alfalfa - Medicago satival L.										46			54		
White melilot - Melilotus albus Med.										21			13		
Total										67			67		
Creeping fescue - Festuca pratensis Huds.	12			2			+				+			2	
Orchard grass - Dactylis glomeratal.	30		1	58		+	23		+	1	23		8	11	
Smooth gromegrass - Bromus inermis Leyss.	4		+	4		+	+				3			+	
Annual meadowgrass - Poa pratensis L.	9			2			5			3	4			2	
Meadow fescue - Festuca rubra L.	8		16	8	1	6	12	+	4	3	9	+	13	5	
White clover - Trifolium repens L.	1			+	+		+				+			+	
Black medic - Medicago lupulina L.	8			5			19				28			59	
White melilot - Melilotus albus Med.	7	+		7			18				9			6	
Tall ryegrass - Arrhenatherum elatius P.B.	13			2			+				+			+	
Bentgrass - Agrostis stolonifera L.	3		4	4		3	4				3		+	1	
Total	95		21	92	1	9	81		4	7	79		21	86	
Lucerne species - Medicago media L.		4			9			8				6			47
Orchard grass - Dactylis glomerata L.		90			80			84				87			39
Total		94			89			92				93			86
White melilot - Melilotus albus Med.			55			82			81						
Remaining species of plants and weeds:															
White campion - Melandium album Garcke	+	+	1	+	1	+	+	+	1	+	+	+	+	+	+
Common yarrow - Achillea millefolium L.	+	+	2	+	+	+	+	+	+	+	+	+	+		+
Creeping thistle - Cirsium arvense scop L.	+							+							
Canadian fleabane - Erigeron canadensis L.	+		+		+	+	+		+	+	+	+	+		
Garden sorrel - Rumex acetosella L.	+		1	+		+			+						
Common wormwood - Artemisia vulgaris L.		+	+	+	+	+			+			+	+		
Heiry rockcress - Arabis arenosa Scop.			2	+		2		+	+			+			
Red clover - Trifolium pratense L.			+	+		+		+				+			
Tufted hairgrass - Deschampsia caespitosa P.B.			+					+							
White goosefoot - Chenopadium album L.				+		+	+		+	3	+	+	+	+	+
Common dandelion - Taraxacum officinale web.									+					+	
Total			6		1	2			1	3					
Bare areas	5	6	18	8	9	7	19	8	14	23	21	7	12	14	14

x/ + - traces (below 1 %)

GROUND COVER OF EXPERIMENTAL PLOTS BY PLANT SPECIES IN PERCENTS

Halemba - prior to II swath
1977

Table 45b

Treatment series	F			G			H			I			O		
Plant species / Seed mixture	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Alfalfa - Medicago sativa L.	66			72			65			74			56		
White melilot	11			8			8			12			17		
Total	77			80			73			86			73		
Creeping fescue - Festuca pratensis Huds.		3			3			+			5			7	
Orchard grass - Dectylis glomerata L.	2	10		+	23		1	16		+	5		2	31	
Smooth bromegrass - Bromus inermis Leyss		+			2		+	+			+			+	
Annual meadowgrass - Poa pratensis L.	2	2		2	5			2		+	4			5	
Meadow fescue - Festuca rubra L.	7	7		8	9		2	12		+	8		11	5	+
White clover - Trifolium repens L.		+			+			2						2	
Black medic - Medicago lupulina L.		60			29			26			27			28	
White melilot - Melilotus albus Med.		4			7			10			40			12	
Tall ryegrass - Arrhenatherum elatius P.B.		+			+			+							
Bentgrass - Agrostis stolonifera L.		2			2			+			+			+	
Total	11	88		10	80		3	68			89		13	96	
Lucerne species - Medicago media L.			33			68			6			65			22
Orchard grass - Dectylis glomerata L.			52			24			26			21			53
Total			85			92			95			86			75
White melilot - Melilotus albus Med.															
Remaining species of plants and weeds:															
White campion - Melandrium album Garcke	+	+	+	+	+	+	+	+	+	+		+		+	
Common yarrow - Achillea millefolium L.			+												
Creeping thistle - Cirsium arvense Scop.															
Canadian fleabane - Erigeron canadensis L.															
Garden sorrel - Rumex acetosella L.								+							
Common wormwood - Artemisia vulgaris L.														+	
Hairy rockcress - Arabis arenosa Scop.															
Red clover - Trifolium pratense L.															
Tufted hairgrass - Deschampsia caespitosa P.B.															
White goosefoot - Chenopodium album L.	+	+	+	+	+		+	+		+					+
Common dandelion - Taraxacum officinale web.															
Total															
Bare areas	12	12	15	10	20	8	24	32	5	14	11	14	14	10	25

x/ +- traces (below 1 %)

GROUND COVER OF EXPERIMENTAL PLOTS BY PLANT SPECIES IN PERCENTS

Konin - prior to II swath 1977

Table 16a

Treatment series	A			B			C			E			F		
Seed mixture / Plant species	2	3	4	2	3	4	2	3	4	1	2	3	1	2	3
Saintfoin - Onobrychis viciaefolia Scop.										40			20		
Axseed - Coronilla varia L.										+					
Total										40			20		
Meadow fescue - Festuca pratensis Huds.	6			4		+	4		+		4			+	
Orchard grass - Dactylis glomerata L.	49			50		+	62		+	4	52		+	9	
Smooth bromegrass - Bromus inermis Leyss	2			2			3				+			+	
Annual meadowgrass - Poa pratensis L.	4			5			5				3			+	
Creeping fescue - Festuca rubra L.	6			6			9			+	11			2	
White clover - Trifolium repens L.	+			+			+				+			+	
Black medic - Medicago lupulina L.	+			1			+				+			2	
White melilot - Melilotus albus Med.	+			+		+	1				+		+	2	
Tall ryegrass - Arrhenatherum elatius P.B.	18			18			7				1			+	
Bentgrass - Agrostis stolonifera L.	5			4			2				3			+	
Total	90			90			93			1	77			15	
Lucerne species - Medicago media L.		14			8			22				23			21
Orchard grass - Dactylis glomerata L.		72			84			67				55			4
Total		86			92			89				78			25
White melilot			25			28			37						
Remaining plant species:															
Barnyard grass - Echinochloa crus-galli L.			18			16			29	+					
Knotweed - Polygonium aviculare L.			15			8			+						
White campion - Melandrium album Garcke	+	+	11	+	+	10	+	+	+	+	+				
Golden camomile - Anthemis tinctoria L.	+	+	4	+	+	+	+	+	+						
Wild camomile - Matricaria chamomilla L.			3	+											
White goosefoot - Chenopodium album						+	+		+	+	+	+	+		+
Field violet - Viola arvensis Murr.									+						
White charlock - Raphanus raphanistrum L.						+									

x/ + - traces (below 1 %)

Table 46a continuation

Treatment series	A			B			C			D			E		
Seed mixture / Plant species	2	3	4	2	3	4	2	3	4	1	2	3	1	2	3
Stork's bill - Erodium cicutarium L. Herit.									+						
Roof bromegrass - Bromus tectorum L.						+									
Common yarrow - Achillea milletolium L.	+			+	+			+		+			+		+
Common wormwood - Artemisia vulgaris L.		+	1			+			+						
Total			55			34			29						
Bare areas	10	14	20	10	8	38	7	11	34	56	23	22	80	85	75

x/ + - traces (below 1 %)

GROUND COVER OF EXPERIMENTAL PLOTS BY PLANT SPECIES IN PERCENTS

Konin - prior to II swath 1977

Table 46b

Treatment series	F			G			H(K)			I			0		
Plant species / Seed mixture	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Sainfoin - Onobrychis viciaefolia Scop.	30			31			70			45			30		
Axseed - Coronilla varia L.	+			1			4			2			+		
Total	30			32			74			47			30		
Meadow fescue - Festuca pratensis Huds.		+			4			+			+			3	
Orchard grass - Dactylis glomerata L.	+	10		1	67		+	11			14		+	13	
Smooth bromegrass - Bromus inermis Leyss		+			+			+			+			+	
Annual meadowgrass - Poa pratensis L.	+	2		+	2			2		+	+			1	
Creaping fescue - Festuca rubra L.		4			3			2			2			3	
White clover - Trifolium repens L.		+			+			+						+	
Black medic - Medicago lupulina L.		6			+			55			+			4	
White melilot - Melilotus albus Med.	+	+			+			+			15			+	
Tall ryegrass - Arrhenatherum elatius P.B.		+			8			+			+			+	
Bentgrass - Agrostis stolonifera L.	+	+		+	2					+	+			+	
Total		22		1	86			70			31			24	
Lucerne species - Medicago media L.			17			44			90			63			43
Orchard grass - Dactylis glomerata L.			13			44			4			+			4
Total			30			88			94			63			47
White melilot - Melilotus albus Med.															
Remaining plant species:															
Barnyard grass - Echinochloa crus-galli L.															
Knotweed - Polygonum aviculare L.	+			1			+								
White campion - Melandrium album Garcke		+													
Golden camomille - Anthemis tinctoria L.															
Wild camomille - Matricaria chamomilla L.	+	+		+	+	+	+	+	+	+	+	+	+	+	+
White goosefoot - Chenopodium album L.															
Field violet - Viola arvensis Murr.															
White charlock - Raphanus raphanistrum L.										+					
Stork's bill - Erodium cicutarium L. Herit															
Roof bromegrass - Bromus tectorum L.				1	+										
Common yarrow - Achillea millefolium L.			+												
Common wormwood - Artemisia vulgaris L.				+											
Total				2											
Bare areas	70	78	70	65	14	12	26	30	6	53	69	37	70	76	53

x/ + - traces (below 1 %)

8. Adopting criterion of ground cover achieved with seed mixtures No.2 and No. 3 (indicators of practical seed mixes for reclamation) the ash treatments can be grouped in the following manner:

Treatment series		Ground cover density (%)	Average (%)
Halemba	A,B,C	87 - 94	91
	D,G,H	82 - 86	85
	E,F,I	86 - 87	87
Konin	A,B,C	88 - 91	90
	D,G,H	78 - 87	82
	E,F,I	20 - 47	31
		Note: seed mixes No. 2 and 3 used for analysis	

YIELDS OF VEGETATION GROWN ON EXPERIMENTAL PLOTS

The yields of the agricultural reclamation plots were determined by cutting, weighing, drying and reweighing the vegetation above the ground. A sample of the harvested material was retained for chemical analyses. The results of green mass weighings are presented in tables 47 and 48. The results of air-dried hay weighings are presented in tables 49 and 50.

Halemba

The first harvest at Halemba was obtained in the late autumn of 1975. The yields of air-dried hay may be summarized by the seed mixes used as follows (the series are arranged from highest yield to lowest yield):

- seed mix No. 1 (lucerne): E,O,F,D,H,I,C (highest 3.5, lowest 0.45 t/ha)

YIELDS OF GREEN MASS (ABOVE GROUND PORTION) FROM EXPERIMENTAL PLOTS HALEMBA

Table 47

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Crops in conversion to t/ha in years							Total in years 1975–1977
			1975	1976			1977			
			swath	swath		total	swath		total	
			I Sep. 29	I Jun. 10	II Aug. 30		I May 31	II Sep 5		
1	2	3	4	5	6	7	8	9	10	11
A-2	Ash + 20 cm layer of soil + NPK	2	13,13	16,32	6,92	23,21	26,95 18,8	14,33 6,88	41,28 25,7 x/	70,73
A-3	– " –	3	7,46	9,42	5,14	14,56	25,15 12,5	6,68 3,38	31,83 15,9 x/	53,85
A-4	– " –	1	3,96	11,38	4,96	16,34	23,72 12,1	12,75 11,00	36,47 33,1 x/	62,80
B-2	Ash + 10 cm layer of soil + NPK	2	10,08	12,66	3,11	15,77	22,52 12,0	11,05 6,75	33,57 18,8 x/	59,42
B-3	– " –	3	7,56	10,01	2,34	12,35	20,00 11,8	8,35 4,83	28,35 16,6 x/	48,26
B-4	– " –	1	4,28	11,04	3,03	14,07	18,75 10,5	14,70 9,88	33,45 20,4 x/	51,80
C-2	Ash + 5 cm layer of soil + NPK	2	5,70	7,47	2,15	9,62	19,28 10,0	12,80 5,58	32,08 15,6 x/	47,40
C-3	– " –	3	5,27	7,85	2,25	10,10	18,50 10,0	6,83 3,55	25,33 13,6 x/	40,70
C-4	– " –	1	2,22	3,59	2,15	5,74	16,22 7,8	8,70 6,55	24,92 14,4 x/	32,88
D-1	Ash + bentonite + NPK	1	4,78	4,30	1,70	6,00	15,75 7,5	9,73 7,58	25,48 15,1 x/	36,26
D-2	– " –	2	2,21	3,52	1,14	4,66	12,78 7,5	6,70 6,88	19,48 14,4 x/	26,38
D-3	– " –	3	1,92	4,08	1,12	5,50	14,30 10,5	6,40 2,70	20,70 13,2 x/	28,12
E-1	Ash + low bog peat + + NPK	1	13,14	5,22	5,86	11,08	25,88 18,1	13,98 12,65	39,86 31,0 x/	64,08
E-2	– " –	2	6,72	6,27	2,16	8,43	22,40 14,8	10,83 5,73	33,23 20,5 x/	48,38
E-3	– " –	3	4,82	4,74	1,37	6,11	19,40 13,6	7,75 3,73	27,15 17,3 x/	38,08
F-1	Ash + mountain peat + + NPK	1	1,11	6,25	1,49	7,74	17,90 13,0	8,28 10,08	26,18 23,1 x/	38,36
F-2	– " –	2	0,26	0,70	0,51	1,21	15,05 9,6	6,30 7,58	21,35 17,2	22,82
F-3	– " –	3	0,33	1,18	0,37	1,55	14,95 9,0	4,65 4,63	19,60 13,6 x/	21,48
G-1	Ash + farm manure + NPK	1	1,26	3,40	0,54	3,94	12,80 8,8	4,78 5,55	17,58 14,4 x/	22,78
G-2	– " –	2	0,17	1,29	0,72	2,01	13,32 9,4	4,70 5,00	18,02 14,4 x/	20,20
G-3	– " –	3	2,10	4,86	0,88	5,74	12,5 9,1	4,73 4,75	17,23 13,8 x/	25,07
H-1	Ash + N2PK	1	4,77	6,35	0,84	7,19	13,50 9,6	7,35 7,50	20,85 17,1 x/	32,81
H-2	– " –	2	1,26	5,12	2,22	7,34	14,68 10,4	9,13 7,35	23,81 17,8 x/	32,41

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Table 47 continuation

1	2	3	4	5	6	7	8	9	10	11
II-3	Ash + N2PK	3	3,22	9,20	3,52	12,72	14,88 11,1	7,00 3,88	21,88 15,5 $^{x/}$	37,82
I-1	Ash + NPK	1	3,31	1,70	0,75	2,45	12,30 8,8	6,38 2,50	18,68 11,1 $^{x/}$	24,12
I-2	- " -	2	1,59	2,99	0,90	3,89	13,25 9,5	7,58 4,88	20,83 14,4 $^{x/}$	26,11
I-3	- " -	3	5,96	4,81	1,50	6,31	10,80 9,5	5,58 4,93	16,38 13,4 $^{x/}$	28,63
0-1	Ash without fertilization (control)	$1^{xx/}$ 1	8,15	5,66	2,42	8,08	10,38 8,2	7,00 8,10	17,38 16,3	33,64
0-2	- " -	$2^{xx/}$ 2	0,53	4,76	2,52	7,28	11,52 8,4	6,23 0,13	17,75 14,5	[illegible]
0-3	- " -	$3^{xx/}$ 3	5,07	10,02	3,50	13,52	12,50 10,2	3,00 5,90	15,50 13,5	31,00

Explanation: $^{x/}$ without fertilization in 1977

$^{xx/}$ fertilization in 1977 only

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- seed mix No. 2 (mixture of grasses): A,B,C,D,E,H,I,F,O,G, (4.0 to 0.1 t/ha)
- seed mix No. 3 (mixture of nitrogen fixing plants with grasses): A,B,C,I,O,E,H,D,G,F (2.7 to 0.15 t/ha)
- seed mix No. 4 (white melilot = white sweetclover): A,B,C (1.5 to 0.6 t/ha).

In 1975, the best results were achieved on plots covered with soil, the best results were achieved on plots covered with soil, and the thickness of the layer determined the yields. Low yields were measured on plots treated with farm manure for unexplained reasons. Low yields were again obtained on these plots in the following years.

High yields were obtained on plots treated with low bog peat seeded with lucerne. Exceptionally high crops of lucerne were measured in subsequent years.

In 1976 with relatively good precipitation conditions, the crops were harvested two times. While it would have been possible to obtain a third cutting, this was not done in the late autumn. The yields were (arranged as in the criteria noted earlier):

- seed mix No. 1: E,O,D,F,H,G,I (highest 3.1, lowest 0.71 t/ha):
- seed mix No. 2: A,B,C,E,O,H,D,I,G,F (0.20 to 0.35 t/ha);
- seed mix No. 3: A,B,C,H,O,I,E,D,G,F (5.1 to 0.44 t/ha);
- seed mix No. 4: A,B,C (3.4 to 1.7 t/ha).

In 1977 favourable weather conditions again allowed two harvests, and growth continued into the late autumn as in 1976. On one half of the plots of all treatment combinations mineral fertilization was conducted as in previous years. On the other half of the plots no fertilizer was added. Yields in 1977 were 50 to 102 percent higher on the fertilized plots.

The crops of hay for the year 1977 can be arranged here as follows:

a) yields from parts of plots fertilized with NP:

- 1-st combination: E (10.99 t/ha),F,D,G,H,O,I (4.78 t/ha)
- 2-nd combination: A(10.82 t/ha),E,B,C,H,G,F,I,D,O (4.51 t/ha)
- 3-rd combination: A(7.11 t/ha),B,C,E,G,F,H,D,I,O (3.81 t/ha)
- 4-th combination: A(9.70 t/ha),B,C (6.02 t/ha)

b) yields from parts of plots not fertilized in 1977:

- 1-st combination: E(8.7 t/ha), F,H,G,D,O,I(2.7 t/ha)
- 2-nd combination: E (6.2 t/ha) A,H,G,F,B,O,I,C,D (3.8 t/ha)
- 3-rd combination: G(4.9 t/ha), E,F,B,I,H,A,O,C,D (3.1 t/ha)
- 4-th combination: A(6.6 t/ha) B,C (3.8 t/ha).

After 3 years of reclamation treatments was found that (table 49) the highest yields of hay (for 3 years) were gathered from the A-2 plot, with placed on it 20 cm layer of fertile soil, and seeded by the combination of grasses with legumes (mix no. 2).

Apart from this the highest crops of the 3-year period were gathered as follows:

- from the mixture No. 3 (lucerne and orchard grass) on plots of A series
- with alfalfa and melilot (mix. no. 1), on plots of E series, fertilized with low moor peat + NP (ash fertilized with low moor peat and NP).

Konin

No cuttings were performed in 1975 due to very unsatisfactory growth of the plants.

In 1976 the experimental plots were seeded again as discussed earlier (section 7). Continued unfavorable weather caused no growth on part of the plots (0, partially I,H,E and F) on other plots only one cutting was obtained. The best results (in 1976) were obtained on plots treated either with soil or with farm manure. The yields of plants could be arranged in a following way starting from highest yield (table 50):

YIELDS OF GREEN MASS (ABOVE GROUND PORTION) FROM EXPERIMENTAL PLOTS
KONIN

Table 48

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Crops in conversion to t/ha in years							
			1975	1976			1977			Total in years 1975–77
			swath	swath		total	swath		total	
			I	I Jun.7	II Sep.23		I Jun.7	II Sep.[illegible]		
1	2	3	4	5	6	7	8	9	10	11
A-2	Ash + 20 cm layer of soil + NPK	2	-	8,09	5,86	13,95	23,48 14,5	22,13 3,9	45,61 x/ 18,4	59,56
A-3	- " -	3	-	8,34	3,42	11,76	23,76 15,0	23,48 10,3	21,15 x/ 25,3	56,39
A-4	- " -	4	-	3,37	1,25	4,62	14,98 9,0	13,53 6,7	28,51 x/ 15,7	33,13
B-2	Ash + 10 cm layer of soil + NPK	2	-	8,22	5,52	13,74	22,82 9,4	13,60 2,5	36,42 x/ 11,9	50,16
B-3	- " -	3	-	7,31	3,52	10,83	22,05 15,8	17,08 11,5	39,13 x/ 27,3	49,96
B-4	- " -	4	-	2,96	2,18	5,14	14,38 7,5	10,75 5,0	25,13 x/ 12,5	30,27
C-2	Ash + 5 cm layer of soil + NPK	2	-	7,15	5,12	12,27	20,35 8,7	12,48 2,0	32,83 x/ 10,7	45,10
C-3	- " -	3	-	6,94	3,06	10,00	18,78 12,9	12,75 7,5	31,53 x/ 20,4	41,53
C-4	- " -	4	-	1,80	2,23	4,03	11,32 11,1	8,10 4,1	19,42 x/ 15,2	23,45
D-1	Ash + tertiary sand + + NPK	1	-	0,14	-	0,14	10,80 6,9	1,15 -	11,95 x/ 6,9	12,09
D-2	- " -	2	-	5,55	3,50	9,05	15,40 6,4	7,70 1,7	23,10 x/ 8,1	32,15
D-3	- " -	3	-	5,82	2,89	8,71	15,02 6,4	8,83 1,2	23,85 x/ 7,6	32,56
E-1	Ash + low bog peat + + NPK	1	-	-	-	-	12,66 7,9	0,40 -	13,06 x/ 7,9	13,06
E-2	- " -	2	-	0,72	0,82	1,54	19,62 10,4	13,10 3,1	32,72 x/ 13,5	34,26
E-3	- " -	3	-	0,17	0,15	0,32	19,38 16,2	14,70 8,9	34,08 x/ 25,1	34,40
F-1	Ash + mountain peat + + NPK	1	-	-	-	-	13,82 8,3	- -	13,82 x/ 8,3	13,82
F-2	- " -	2	-	0,43	1,33	1,76	18,80 12,1	8,43 3,0	27,23 x/ 15,1	28,99
F-3	- " -	3	-	0,41	0,13	0,54	16,82 15,8	11,40 9,7	28,22 x/ 25,5	28,76
G-1	Ash + farm manure + + NPK	1	-	0,62	-	0,62	17,55 11,4	1,05 -	18,60 x/ 11,4	19,22
G-2	- " -	2	-	10,06	2,98	13,04	26,32 11,3	9,03 2,5	35,35 x/ 13,8	48,39
G-3	- " -	3	-	7,54	2,49	10,03	24,20 17,6	12,43 10,3	36,63 x/ 27,9	46,66
H(K)-1	Ash + green manure + N2PK	1	-	-	-	-	18,52 16,8	- -	18,52 x/ 16,8	18,52

Table 48 continuation

1	2	3	4	5	6	7	8	9	10	11
H(K)-2	Ash + green manure + N2PK	2	-	-	1.80	1.80	24.12 22.1	10.58 5.1	34.70 27.2 x/	36.50
H(K)-3	- " -	3	-	-	0.05	0.05	20.52 18.0	13.15 8.7	33.67 26.7 x/	33.72
I-1	Ash + NPK	1	-	-	-	-	13.92 7.8	- -	13.92 7.8 x/	13.92
I-2	- " -	2	-	-	0.98	0.98	22.48 13.6	6.83 2.8	29.31 16.4 x/	30.29
I-3		3	-	-	-	-	17.72 15.3	5.50 5.4	23.22 20.7 x/	23.22
0-1	Ash without fertilization (control)	1 xx/ 1	-	-	-	-	5.75 2.7	0.25 0.2	6.00 2.9	6.00
0-2	- " -	2 xx/ 2	-	-	-	-	9.62 7.6	2.30 1.3	11.92 8.9	11.92
0-3	- " -	3 xx/ 3	-	-	-	-	15.52 13.0	5.40 4.4	20.92 17.1	20.92

Explanation: x/ without fertilization in 1977

xx/ fertilization in 1977 only

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YIELDS OF HAY FROM EXPERIMENTAL PLOTS (air - dried mass)
HALEMBA

Table 49

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Crops in conversion to t/ha							Total in years 1975-1977	Ratio of hay to green mass
			1975	1976			1977				
			I swath	swath I Jun. 10	swath II Aug. 30	total	swath I May 31	swath II Sep. 5	total		
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm layer of soil + NPK	2	4,03	3,69	2,51	6,20	5,75 3,4	5,07 2,4	10,82 x/ 5,8	21,05	0,298
A-3	- " -	3	2,69	2,93	2,19	5,12	4,20 2,1	2,91 1,5	7,11 x/ 3,6	14,92	0,277
A-4	- " -	4	1,53	1,63	1,78	3,41	4,97 2,5	4,73 4,1	9,70 x/ 6,6	14,64	0,233
B-2	Ash + 10 cm layer of soil + NPK	2	2,82	2,32	1,24	3,56	4,39 2,3	4,29 2,6	8,68 x/ 4,9	15,06	0,253
B-3	- " -	3	2,12	2,27	1,10	3,37	3,44 1,9	3,39 2,0	6,82 x/ 3,9	12,31	0,255
B-4	- " -	4	1,26	1,90	1,21	3,11	3,28 1,8	5,29 3,6	8,57 x/ 5,4	12,94	0,250
C-2	Ash + 5 cm layer of soil + NPK	2	1,54	1,70	0,85	2,55	3,62 1,9	4,67 2,0	8,29 x/ 3,9	12,38	0,261
C-3	- " -	3	1,65	2,10	1,05	3,15	3,01 1,7	2,68 1,4	5,69 x/ 3,1	10,49	0,258
C-4	- " -	4	0,62	0,90	0,77	1,67	2,74 1,3	3,28 2,5	6,02 x/ 3,8	8,31	0,253
D-1	Ash + bentonite + + NPK	1	1,27	1,28	0,68	1,96	3,08 1,5	3,60 2,8	6,68 x/ 4,3	9,91	0,273
D-2	- " -	2	0,60	0,86	0,39	1,25	2,56 1,5	2,20 2,3	4,76 x/ 3,8	6,61	0,251
D-3	- " -	3	1,25	0,95	0,63	1,58	2,62 1,9	2,89 1,2	5,51 x/ 3,1	8,34	0,268
E-1	Ash + low bog peat + + NPK	1	3,50	1,31	1,79	3,10	6,08 4,3	4,91 4,4	10,99 x/ 8,7	17,59	0,275
E-2	- " -	2	1,25	1,38	0,75	2,13	5,16 3,8	4,45 2,4	9,61 x/ 6,2	12,99	0,280
E-3	- " -	3	1,29	1,11	0,57	1,68	3,38 3,2	2,30 1,6	6,68 x/ 4,8	9,65	0,253
F-1	Ash + mountain peat + NPK	1	1,30	1,49	0,45	1,94	4,87 3,5	2,84 3,5	7,71 x/ 7,0	10,95	0,285
F-2	- " -	2	0,12	0,13	0,22	0,35	3,67 2,3	2,27 2,7	5,94 x/ 5,0	6,41	0,281
F-3	- " -	3	0,15	0,27	0,17	0,44	3,63 2,2	2,17 2,2	5,70 x/ 4,4	6,29	0,293
G-1	Ash + farm manure + + NPK	1	0,45	0,75	0,23	0,98	3,99 2,7	1,77 2,0	5,76 x/ 4,7	7,19	0,316
G-2	- " -	2	0,09	0,35	0,35	0,70	1,37 3,2	1,81 1,9	6,18 x/ 5,1	6,97	0,343
G-3	- " -	3	0,59	1,07	0,47	1,54	4,00 2,9	1,95 2,0	5,95 x/ 4,9	8,08	0,322
H-1	Ash + N2PK	1	1,02	1,59	0,34	1,93	2,87 2,1	2,86 2,9	5,73 x/ 5,0	8,68	0,265
H-2	- " -	2	0,41	0,93	1,03	1,96	3,64 2,6	3,18 2,6	6,82 x/ 5,2	9,19	0,284

Table 49 continuation

1	2	3	4	5	6	7	8	9	10	11	12
H-3	Ash + N2PK	3	0,77	2,13	1,39	3,52	2,86 2,1	2,78 1,7	5,64 x/ 3,8	9,93	0,263
I-1	Ash + NPK	1	0,86	0,43	0,28	0,71	2,52 1,8	2,26 0,9	4,78 x/ 2,7	6,35 7,26	0,263
I-2	- " -	2	0,39	0,77	0,38	1,15	2,93 2,1	2,79 1,8	5,72 x/ 3,9	7,26	0,276
I-3	- " -	3	1,67	1,32	0,56	1,88	2,34 2,1	2,63 1,8	4,97 x/ 3,9	8,52	0,297
0-1	Ash without fertilization (control)	$1^{xx/}$	2,06	1,29	0,96	2,26	2,51 1,5	2,66 2,6	5,17 4,1	9,48	0,282
0-2	- " -	$2^{xx/}$	0,11	1,01	1,06	2,07	2,12 2,2	2,39 2,5	4,51 4,7	6,69	0,262
0-3	- " -	$3^{xx/}$	1,66	1,66	1,32	2,98	2,40 2,2	1,41 1,3	3,81 3,5	8,45	0,248

Explanation: x/ without fertilization in 1977
xx/ fertilization in 1977 only

- seed mix No. 1: G,D (0.20 to 0.04 t/ha)
- seed mix No. 2: A,B,G,C,D,H,K,F,E,I (5.10 to 0.36 t/ha)
- seed mix No. 3: A,B,G,C,D,F,E,H,K (4.42 to 0.02 t/ha)
- seed mix No. 4: B (1.26 t/ha),A,C (1.25 t/ha).

In 1977 more favourable weather conditions resulted in higher yields and, in fact, higher yields than at Halemba. The plots at Konin were also split into fertilized and unfertilized segments in 1977. Similarly to that measured at Halemba, the crops grown on fertilized plots at Konin were from 5 to 90 percent higher than on the unfertilized plots. All plots were cut twice in 1977 and the yields measured and categorized by seed mix as follows (from highest to lowest yield):

a) plots fertilized in 1977 (table 50):
  - seed mix No. 1: G(4.97 t/ha), H,D,I,E,F,C (1.69 t/ha)
  - seed mix No. 2: A(13.78 t/ha),B,G,C,H,I,F,E,D,O (3.79 t/ha)
  - seed mix No. 3: A(14.27 t/ha),B,G,C,E,H,F,D,O,I (7.10 t/ha)
  - seed mix No. 4: A(8.57 t/ha), B,C (5.54 t/ha);

b) plots not fertilized in 1977 (table 50):
  - seed mix No. 1: H(4.5 t/ha),G,D,E,F,I,O (0.8 t/ha)
  - seed mix No. 2: H(8.0 t/ha),A,I,F,G,B,E,C,O,D (2.9 t/ha)
  - seed mix No. 3: G(9.0 t/ha),B,A,F,E,H,C,I,O,D (3.0 t/ha)
  - seed mix No. 4: A(4.8 t/ha),C,B (3.9 t/ha).

After 3 years of the reclamation was found, that highest yields of hay (for 3 years), were gathered similarly as in Halemba from the A-2 plot with a brought on it 20 cm layer of fertile soil and seeded with combination of grasses with legumes (mix no. 2).

Highest yields of other mixes were obtained from the following plots:

- seed mix No. 3 (alfalfa with orchard grass) on A-3 plots (addition of a 20 cm layer of fertile soil + NPK), on B-3 (addition of a 10 cm layer of fertile soil + NPK), G-3 (added farm manure + NPK) - 15.22 to 16.13 t/ha

- seed mix No. 4 (white melilot) on A-4 plots (20 cm layer of fertile soil + NPK) - 9.83 t/ha
- seed mix No. 1 (sainfoin and crown vetch) on G-1 plots (farm manure fertilization + NPK) - 5.17 t/ha.

CROP UTILITY

The scope and method of investigations

Chemical analyses were performed on hay to determine its utility as fodder for animals and to determine relationships between macro and microelements contained in ashes, in fertilizers, and in plants. Radioactivity of the crops were also determined.

Samples were collected from all treatment combinations wherever growth was adequate. From 1.0 to 2.0 kg of vegetation were dried to 7 percent moisture content. Laboratory tests were used to determine the fodder (protein) content, ash, and chemical composition. The content of macro and microelements was determined with standard methods employed in Polish chemical - agricultural stations [43] . The results are presented in tables 51 and 52. Radioactive properties of hay were determined with methods previously discussed in chapter: Radioactivity of ashes. The results of these tests are also given in tables 53 and 54.

Halemba

The content of nitrogen (table 41) in the yields of the crop cut in 1977 (after 3 years of reclamation) fluctuated from 2.02 % (mix no.2 from plot covered with 20 cm layer of fertile soil + NPK) to 2.92 % (mix no. 1, from plot fertilized with NPK only). The lowest content of nitrogen (1.61 %) was found in samples of mix no. 3, grown on the 0 control plot, without any applied fertilization). The content of this macroelement in cultivated normal soils amounts to:

- in grasses - on the average to 1.22 % (max. 2.05 %),
- in legumes - average 2.88 % (max. 3.63 %).

CROPS OF H/ FROM EXPERIMENTAL PLOTS (air dried mass)
KONIN

Table 50

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Crops in conversion to t/ha							Total in years 1975–77	Ratio of hay to green mass
			1975	1976			1977				
			I swath	swath		total	swath		total		
				I Jun. 7	II Sep. 23		I Jun. 7	II Sep. 8			
1	2	3	4	5	6	7	8	9	10	11	12
A-2	Ash + 20 cm layer of fertile soil + NPK	2	-	2,99	2,11	5,10	8,31 5,1	5,47 1,0	13,78 x 6,1	18,88	0,317
A-3	- " -	3	-	2,97	1,45	4,42	9,11 5,8	5,16 2,5	14,27 x 8,3	15,69	0,278
A-4	- " -	4	-	0,81	0,45	1,26	5,12 3,1	3,45 1,7	8,57 x 4,8	9,83	0,297
B-2	Ash + 10 cm layer of fertile soil + NPK	2	-	2,85	1,98	4,83	8,67 3,6	4,01 0,7	12,68 x 4,3	17,51	0,349
B-3	- " -	3	-	2,34	1,65	3,99	7,72 5,5	4,42 3,0	12,14 x 8,5	16,13	0,323
B-4	- " -	4	-	0,77	0,78	1,55	4,64 2,4	3,23 1,5	7,87 x 3,9	9,42	0,311
C-2	Ash + 5 cm layer of soil + NPK	2	-	2,43	1,82	4,25	7,12 3,0	3,54 0,6	10,66 x 3,6	14,91	0,331
C-3	- " -	3	-	2,20	1,43	3,63	7,12 4,9	3,54 2,1	10,66 x 7,0	14,29	0,344
C-4	- " -	4	-	0,44	0,81	1,25	3,18 3,1	2,36 1,2	5,54 x 4,3	6,79	0,290
D-1	Ash + tertiary sand + + NPK	1	-	0,04	-	0,04	3,64 2,3	0,30 -	3,94 x 2,3	3,98	0,329
D-2	- " -	2	-	1,89	1,26	3,15	5,33 2,4	2,29 0,5	7,62 x 2,9	10,77	0,335
D-3	- " -	3	-	1,83	1,28	3,11	5,7 2,7	2,45 0,3	8,22 x 3,0	11,33	0,346
E-1	Ash + low bog peat + + NPK	1	-	-	-	-	3,42 2,1	0,11 -	3,53 x 2,1	3,53	0,270
E-2	- " -	2	-	0,19	0,29	0,48	5,73 3,0	3,32 0,8	9,05 x 3,8	9,53	0,278
E-3	- " -	3	-	0,05	0,64	0,69	6,36 5,3	3,13 1,9	9,49 x 7,2	10,18	0,296
F-1	Ash + mountain peat + + NPK	1	-	-	-	-	3,53 2,1	- -	3,53 x 2,1	3,53	0,255
F-2	- " -	2	-	0,13	0,47	0,60	6,62 4,2	2,51 0,9	9,13 x 5,1	9,73	0,336
F-3	- " -	3	-	0,12	0,06	0,18	5,91 5,6	2,49 2,1	8,40 x 7,7	8,58	0,298
G-1	Ash + farm manure + + NPK	1	-	0,20	-	0,20	4,69 3,0	0,28 -	4,97 x 3,0	5,17	0,269
G-2	- " -	2	-	3,16	1,08	4,24	9,92 4,2	2,48 0,7	12,40 x 4,9	16,64	0,344
G-3	- " -	3	-	2,48	1,33	3,81	8,28 6,4	3,13 2,6	11,41 x 9,0	15,22	0,326
H(K)-1	Ash + green manure + N2PK	1	-	-	-	-	4,96 4,5	- -	4,96 x 4,5	4,96	0,268
H(K)-2	- " -	2	-	-	0,62	0,62	7,38 6,8	2,55 1,2	9,93 x 8,0	10,55	0,289

Table 50 continuation

1	2	3	4	5	6	7	8	9	10	11	12
H(K)-3	Ash + green manure + N2PK	3	-	-	0,02	0,02	6,15 5,4	2,72 1,8	8,87 7,2 x	8,89	0,264
I-1	Ash + NPK	1	-	-	-	-	3,55 2,0	- -	3,55 2,0 x	3,55	0,255
I-2	- " -	2	-	-	0,36	0,36	7,60 4,6	1,69 0,7	9,29 5,3 x	9,65	0,319
I-3	- " -	3	-	-	-	-	5,88 5,1	1,22 1,2	7,10 6,3 x	7,10	0,306
0-1	Ash without fertilization (control)	$1^{xx/}$	-	-	-	-	1,62 0,8	0,07 0,0	1,69 0,8	1,69	0,282
0-2	- " -	$2^{xx/}$	-	-	-	-	3,22 2,7	0,57 0,3	3,79 3,0	3,79	0,318
0-3	- " -	$3^{xx/}$	-	-	-	-	6,68 4,3	1,38 1,1	8,06 5,4	8,06	0,385

Explanation: x/ without fertilization in 1977

xx/ fertilization in 1977 only

CHEMICAL ANALYSIS OF VEGETATION MATERIAL SAMPLES COLLECTED FROM EXPERIMENTAL PLOTS IN HALEMBA

(samples collected May 31, 1977)

Table 51

Samle designation / Numbers of plots	Description of plot treatment	Seed mixture	Hay humidity %	Ash %	Protein %	Macroelement content in %					Microelement content in ppm						
						N	P_2O_5	K_2O	CaO	MgO	B	Cu	Mn	Mo	Zn	Fe	Co
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A-2	Ash + 20 cm layer of soil + + NPK	2	10,95	4,91	12,63	2,02	0,49	1,10	0,61	0,56	9,5	7,0	66,0	0,80	118,0	725	0,34
A-3	- " -	3	10,88	4,01	13,81	2,21	0,49	1,05	0,58	0,63	9,0	7,0	84,0	0,75	125,0	360	0,31
A-4	- " -	4	10,83	5,40	13,38	2,14	0,53	1,70	0,69	0,53	10,5	6,5	98,0	0,80	137,5	575	0,34
B-2	Ash + 10 cm layer of soil + NPK	2	10,73	4,41	13,06	2,09	0,49	1,69	0,63	0,53	7,5	6,0	86,0	0,75	131,0	342	0,31
B-3	- " -	3	10,90	4,27	13,13	2,10	0,49	1,30	0,66	0,65	12,0	5,0	56,5	1,25	125,0	285	0,33
B-4	- " -	4	11,02	4,91	13,56	2,17	0,53	1,41	0,64	0,68	12,0	4,5	44,0	1,00	80,0	590	0,43
C-2	Ash + 5 cm layer of fertile soil + NPK	2	11,23	4,84	14,25	2,28	0,53	1,71	0,74	0,71	13,5	5,0	56,0	1,60	80,0	415	0,34
C-3	- " -	3	11,34	4,71	14,56	2,33	0,42	1,61	0,71	0,78	15,5	3,5	37,0	2,00	66,0	415	0,42
C-4	- " -	4	11,03	5,85	16,13	2,58	0,38	2,01	0,95	1,05	19,5	3,5	31,0	1,20	75,0	56·	0,31
D-1	Ash + bentonite + NPK	1	10,98	6,02	17,50	2,80	0,58	2,53	0,83	0,96	24,5	3,5	31,0	2,00	62,0	465	0,34
D-2	- " -	2	11,14	5,86	15,44	2,47	0,53	2,60	0,77	0,96	18,5	3,0	31,0	1,30	55,0	652	0,34
D-3	- " -	3	11,12	5,94	16,75	2,68	0,42	2,77	0,68	0,96	21,5	3,5	24,0	1,70	51,0	320	0,31
E-1	Ash + low bog peat + NPK	1	11,03	6,68	16,31	2,61	0,70	1,69	1,71	1,00	46,0	5,0	28,5	3,50	53,5	625	0,31
E-2	- " -	2	10,74	6,23	13,88	2,22	0,58	1,65	1,54	0,76	20,5	4,7	28,0	3,10	48,5	720	0,32
E-3	- " -	3	10,84	5,85	12,81	2,05	0,49	1,78	0,78	0,71	20,0	4,0	33,5	2,00	45,0	825	0,37
F-1	Ash + mountain peat + NPK	1	11,16	7,87	17,00	2,72	0,58	1,62	1,37	1,00	41,0	4,7	38,0	2,95	47,5	1075	0,40
F-2	- " -	2	11,28	5,76	13,88	2,22	0,58	1,81	1,21	1,00	36,5	3,5	30,0	2,35	46,5	1050	0,31
F-3	- " -	3	11,26	7,53	14,00	2,24	0,49	1,84	0,96	1,08	34,5	6,0	45,0	2,95	47,0	1488	0,37
G-1	Ash + farm manure + NPK	1	10,69	7,09	16,19	2,59	0,53	1,71	1,18	1,34	38,0	4,5	39,0	2,60	53,5	1037	0,35
G-2	- " -	2	10,91	6,09	13,13	2,10	0,58	2,04	0,89	1,01	22,0	4,0	41,0	2,10	48,0	1005	0,28
• G-3	- " -	3	10,78	6,08	15,25	2,44	0,63	1,89	0,91	1,01	28,0	4,0	32,0	2,50	50,0	690	0,28

Table 51 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H-1	Ash + N2PK	1	10.34	9.12	15.88	2.54	0.58	1.81	0.94	1.01	31.5	6.0	65.5	3.45	112.0	1775	0.43
H-2	- " -	2	10.62	7.33	14.44	2.31	0.53	1.90	1.04	0.90	29.0	4.7	45.0	2.95	58.5	1143	0.40
H-3	- " -	3	10.78	5.71	14.44	2.31	0.53	1.69	0.89	0.93	31.5	3.5	31.0	3.65	58.5	645	0.36
I-1	Ash + NPK	1	11.63	5.98	18.25	2.92	0.49	1.89	1.02	1.23	26.5	6.0	37.5	2.15	66.5	850	0.43
I-2	- " -	2	11.53	5.74	16.13	2.58	0.49	1.87	0.85	1.00	20.0	3.5	26.0	1.40	51.0	420	0.37
I-3	- " -	3	11.38	5.22	15.25	2.44	0.42	1.71	0.68	0.93	20.0	3.5	21.0	1.80	43.0	350	0.36
C-1	Ash without fertilization (control)	1 x/	10.81	5.94	14.69	2.35	0.49	1.45	0.86	0.86	24.0	3.5	27.5	2.00	51.5	620	0.39
		1	11.03	6.70	15.88	2.54	0.53	1.55	1.46	1.16	37.5	3.5	39.0	6.15	62.0	725	0.37
C-2	- " -	2 x/	10.83	5.75	15.63	2.50	0.49	1.87	1.07	1.00	35.0	3.0	27.0	3.00	53.0	590	0.29
		2	10.56	5.77	11.38	1.82	0.49	1.78	0.85	0.75	21.0	3.0	29.5	2.25	44.5	565	0.43
C-3	- " -	3 x/	11.05	5.40	15.56	2.49	0.49	2.01	0.80	0.93	31.0	3.0	25.5	3.05	52.0	585	0.30
		3	10.43	4.51	10.06	1.61	0.53	1.61	0.56	0.63	14.0	2.0	27.0	2.25	33.5	320	0.23

Explanation: x/ fertilization in 1977 only

CHEMICAL ANALYSIS OF VEGETATION MATERIAL SAMPLES COLLECTED FROM EXPERIMENTAL PLOTS IN KONIN

(samples collected June 17, 77)

Table 32

Sample designation / Numbers of plots	Description of plots treatment	Seed mixture	Hay humidity %	Ash content %	Protein content %	Macroelement content in %					Microelement content in ppm						
						N	P_2O_5	K_2O	CaO	MgO	B	Cu	Mn	Mo	Zn	Fe	Co
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A-2	Ash + 20 cm of fertile soil + NPK	2	10.02	4.40	8.88	1.42	0.38	1.97	0.61	0.35	39.0	3.0	33.0	0.50	20.5	132	0.22
A-3	- " -	3	9.91	4.60	8.31	1.33	0.38	2.18	0.53	0.38	34.0	3.5	39.0	0.50	20.0	109	0.23
A-4	- " -	4	11.53	5.78	9.31	1.49	0.58	2.46	1.22	0.58	35.5	4.0	41.0	0.90	18.0	156	0.25
B-2	Ash + 10 cm of fertile soil + NPK	2	9.76	4.78	7.56	1.21	0.42	1.77	0.61	0.73	50.0	2.6	28.0	0.40	16.5	105	0.23
B-3	- " -	3	9.12	4.40	7.38	1.18	0.49	1.85	0.61	0.38	62.0	3.0	36.5	0.60	15.0	105	0.29
B-4	- " -	4	10.51	5.50	9.00	1.44	0.49	1.96	1.15	0.46	55.0	3.7	34.5	0.95	17.5	159	0.31
C-2	Ash + 5 cm of fertile soil + NPK	2	9.79	4.87	7.38	1.18	0.53	1.86	0.61	0.42	66.0	3.0	31.5	0.50	18.0	104	0.36
C-3	- " -	3	9.71	4.93	7.88	1.26	0.42	2.00	0.55	0.42	61.0	3.0	29.0	0.90	15.5	106	0.37
C-4	- " -	4	10.68	7.06	13.38	2.14	0.49	2.01	2.11	0.83	108.0	4.5	36.0	3.40	18.5	174	0.39
D-1	Ash + tertiary sand + NPK	1	10.00	4.46	9.00	1.44	0.38	1.94	0.86	0.46	128.0	3.5	34.5	3.60	13.5	129	0.31
D-2	- " -	2	9.53	4.01	7.00	1.12	0.31	1.85	0.54	0.38	110.0	2.0	37.0	0.65	12.5	100	0.36
D-3	- " -	3	9.66	4.71	9.50	1.52	0.38	1.93	0.64	0.56	116.0	2.6	34.0	0.65	11.5	122	0.36
E-1	Ash + low bog peat + NPK	1	9.79	5.40	10.88	1.74	0.42	2.19	1.12	0.50	160.0	3.6	38.0	5.75	15.0	250	0.48
E-2	- " -	2	9.74	5.99	8.75	1.40	0.31	2.15	0.90	0.42	122.0	3.5	41.0	1.50	9.5	600	0.43
E-3	- " -	3	10.12	5.80	9.50	1.52	0.31	2.18	1.35	0.53	110.0	3.7	32.5	1.45	12.5	144	0.43
F-1	Ash + mountain peat + NPK	1	10.33	5.41	10.00	1.60	0.49	2.42	0.98	0.50	160.0	3.5	41.5	4.90	16.5	131	0.30
F-2	- " -	2	9.82	5.25	7.88	1.26	0.26	2.21	0.86	0.38	92.0	3.0	30.0	1.60	9.5	105	0.34
F-3	- " -	3	10.10	6.90	11.19	1.79	0.38	2.36	1.82	0.63	104.0	3.5	29.0	1.50	11.0	250	0.43
G-1	Ash + farm manure + NPK	1	10.68	5.64	9.31	1.49	0.58	2.32	1.03	0.46	138.0	3.5	42.0	4.70	16.5	258	0.40
G-2	Ash + farm manure + NPK	2	10.43	5.36	6.88	1.10	0.31	1.89	0.64	0.38	102.0	3.0	39.5	0.80	17.5	147	0.45
G-3	- " -	3	10.27	6.43	8.00	1.28	0.38	2.80	1.12	0.46	108.0	3.0	41.0	1.25	13.5	141	0.37
H(E.)-1	Ash + green manure + N2PK	1	11.35	5.63	11.25	1.80	0.49	2.37	1.14	0.56	275.0	2.5	37.0	4.30	16.5	800	0.37

Table 52 continuation

21	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
II(K)-2	Ash + green manure + N2PK	2	10,43	5,58	9,19	1,47	0,42	2,30	1,13	0,50	76,0	2,2	34,5	2,45	12,5	140	0,34
II(K)-3	- " -	3	9,11	7,95	10,10	1,63	0,31	2,58	2,27	0,83	126,0	3,2	37,0	2,45	13,5	400	0,36
I-1	Ash + NPK	1	9,66	6,48	11,19	1,79	0,05	2,40	1,31	0,68	350,0	3,5	40,0	6,50	16,[illegible]	300	0,40
I-2	- " -	2	9,23	5,82	7,75	1,24	0,31	2,32	1,02	0,42	64,0	2,5	23,0	1,95	12,5	113	0,40
I-3	- " -	3	9,53	6,60	10,38	1,66	0,26	1,94	1,87	0,68	90,0	3,5	24,5	1,80	12,5	152	0,35
O-1	Ash without fertilization (control)	1 x/	10,18	5,28	8,25	1,32	0,40	2,20	0,97	0,42	132,0	3,0	42,5	3,30	12,0	158	0,39
		1	9,81	5,89	8,88	1,42	0,42	2,04	1,18	0,56	185,0	3,5	47,0	8,50	20,0	900	0,33
O-2	- " -	2 x/	9,95	6,06	7,88	1,26	0,31	1,87	1,37	0,56	220,0	3,0	42,5	3,20	12,0	147	0,23
		2	9,61	5,53	6,88	1,10	0,26	1,97	1,11	0,50	114,0	2,0	45,0	2,85	11,5	115	0,25
O-3	- " -	3 x/	9,83	8,98	10,88	1,74	0,26	2,80	2,60	0,30	136,0	2,5	33,5	2,80	12,5	125	0,37
		3	9,98	8,80	11,06	1,77	0,26	2,87	2,58	0,73	110,0	2,7	33,0	2,75	13,[illegible]	185	0,36

Explanation: x/ fertilization in 1977 only

This means, that the content of this component in the yields of plants from Halemba may be considered as normal. Similarly no phosphorus famine in plants was observed. While the P_2O_5 content in grasses cultivated on normal soils amounts to 0.49 % and in pulse crops to 0.41 percent, then in plants collected from plots in Halemba the content of this macroelement was estimated as 0.38 % (combination from C-3 plot) to 0.70 % (E-1 plots).

Grasses and papilionaceae cultivated in natural soils contain up to 3.4 percent K_2O whereby this value is strongly differentiated dependent on the plant species. It was found in samples from Halemba the content of K_2O being from 1.05 % (A-3 plot) to 2.77 % (plot fertilized with bentonite + NPK). On the basis of acquired results one could assume, that in a further reclamation work this potassium deficiency would have to be supplemented. There is however fear, that the addition of potassium may hinder as substitute the uptake of sodium, which would decrease the rate of desalinization. Necessary here is to carry out supplementary tests regarding the potassic fertilization.

The content of CaO in plants cultivated on agricultural soils amounts to:

- in grasses on average to 0.54 % (max. 0.90 %),
- in legumes average 2.95 % (max. 3.8 %).

One can say therefore, that the ascertained reserves in yields of calcium are not sufficient and amount from 0.58 % (the A-2 plots), to 1.71 % (on E-1 plots). This affects particularly the mixtures with greater proportion of legumes (mix. no. 3 and no. 4), where the CaO content did not exceed 0.96 % (F-3 plots). This problem should be brought to light in further investigations of aluminous ash reclamation.

The limitary values of microelements in lucerne, obtaining in Polish conditions are as follows in ppm:

	min	max	average
B	25.5	54.0	36.0
Cu	5.6	18.8	10.4
Mn	26.3	60.2	35.8

	min	max	average
Mo	0.01	2.76	0.68
Zn	28.8	50.2	39.0
Fe	117	247	160
Co	0.05	0.29	0.13

In the light of these data in reference to yields of vegetation collected at Halemba it can be said that:

1) The content of boron is insufficient in plants gathered from plots fertilized with fertile soil, in other combinations it fluctuates within 18.5 ppm (D-2) to 46 ppm (E-1);

2) The content of copper is not sufficient in most cultivation combinations, and in yields gathered from control plots is exceptionally low (2 - 3.5 ppm);

3) The content of manganese fluctuates from 21 ppm (plants from I-3 plot), to 98 ppm (plants from A-4 plot), which can be considered as maximum, higher Mn values contain plants growing on plots fertilized with fertile soil.

4) The content of molybdenum is exceeding the given above figure of 2.76 ppm in plants coming from plots supplied with peat (E-1, E-3, F-1, F-3), with mineral fertilizers in double dose (H-1, H-2, H-3) and from the not fertilized control plots (0-1, 0-2, 0-3); a particularly high Mo value was found in the mixture no. 1 (lucerne and melilot) coming from the control plot 0-1 (6.15 ppm).

5) The content of Zn stays within the permitted limits only in plants coming from some of the plots; considering that harmful for health is the content of Zn above the 50 ppm level the yields of following plots are not fit for animal consumption:

   - the A, B and C combinations with brought on fertile soil + NPK - 66 to 137.5 ppm Zn
   - the D combinations with bentonite fertilization + NPK - 52 to 62 ppm Zn

RADIOACTIVITY OF CROPS COLLECTED FROM EXPERIMENTAL PLOTS IN [illegible]
(samples taken [illegible] Sep. 9, 1976)

Table [illegible]

Sample designation (number of plots)	Description of soil treatment	Seed mixture	Alpha activity (pCi per g of mass)		Beta activity (pCi per g of mass)		Gamma activity (pCi per g of mass)	
			green	dry	green	dry	green	dry
1	2	3	4	5	6	7	8	9
A-2	Ash + 20 cm layer of soil + NPK	2	6,98	19,43	4.21	[illegible]	traces	traces
A-3	" " "	3	[illegible]	7.10	4.47	[illegible]	1.21	[illegible]
A-4	" " "	4	[illegible]	34.06	2.37	14.98	5.76	10,30
B-3	Ash + 10 cm layer of soil + NPK	3	17,04	37,58	9,67	20,57	traces	traces
C-3	Ash + 5 cm layer of soil + NPK	3	[illegible]	17,70	5,36	11,45	traces	traces
D-3	Ash + bentonite + NPK	3	7,10	16.26	9,65	21,61	0,59	1,34
E-3	Ash + low bog peat + NPK	3	traces	traces	8.61	20.25	traces	traces
F-3	Ash + mountain peat + NPK	3	traces	traces	7.96	17.37	0,64	2.04
G-3	Ash + farm manure + NPK	3	20,87	39,18	8,29	15,56	traces	traces
H-3	Ash + N2PK	3	4,07	10,45	5,38	13,80	"	"
I-3	Ash + NPK	3	5,19	13,96	6,88	18,51	0,74	1,96
K-3	Ash without fertilization - control	3	5,10	13,37	6,39	17,79	traces	traces

RADIOACTIVITY OF CROPS COLLECTED FROM EXPERIMENTAL PLOTS IN KONIN
(samples taken on the Sep. 6,1976)

Table 54

Sample designation / Numbers of plots	Description of plot treatment	Seed mixture	Alpha activity (pCi per 1 g of mass)		Beta activity (pCi per 1 g of mass)		Gamma activity (pCi per 1 g of mass)	
			green	dry	green	dry	green	dry
1	2	3	4	5	6	7	8	9
A-2	Ash + 20 cm layer of soil + NPK	2	12.76	22.43	10.66	18.74	5.77	10.15
A-3	- " -	3	27.09	43.34	9.47	15.15	2.08	3.32
A-4	- " -	4	1.98	4.16	5.77	12.15	traces	traces
B-3	Ash + 10 cm layer of soil + NPK	3	13.11	25.27	6.18	11.92	2.60	5.02
C-3	Ash + 5 cm layer of soil + NPK	3	13.13	24.53	9.70	18.12	traces	traces
D-3	Ash + tertiary sand + NPK	3	11.16	27.95	7.80	19.50	traces	traces
E-3	Ash + low bog peat + NPK	3	11.80	26.30	6.03	13.44	3.05	6.79
F-3	Ash + mountain peat + NPK	3	traces	traces	8.43	17.98	4.63	9.88
G-3	Ash + farm manure + NPK	3	12.37	27.48	9.06	20.14	4.62	10.27
H(K)-3	Ash + green manure + N2PK	3	4.70	12.65	7.35	20.08	traces	traces
I-3	Ash + NPK	3	no crop					
0-3	Ash without fertilization - control	3	no crop					

- the H combinations with double mineral fertilization - 58.5 to 112 ppm Zn
- the 0 combinations (control) and I (with mineral NPK fertilization) - 51.5 to 66.5 ppm Zn.

6) The content of iron is number of times higher in all tested samples in comparison with normal vegetation, which fact speaks of intensive uptake of this element from the soil (320 to 1775 ppm of Fe).

7) The content of cobalt stays within the provided above limits or is slightly higher (within limits to 0.43 ppm).

In summary one may state, that the acquired yields of hay from particular plots in few cases only are fit for use as fodder for animals, and this is due to an excessive amount of zinc or of molybdenum. Particular amendments improving growth of plants by and large, do not improve the fodder value of hay. In the given example it seems, that excessive quantities of zinc are derived from fertile soil used in the A,B and C combinations to meliorate the ashes. Hence the proposition that one has to consider the exact composition and properties of substances utilized to improve ashes. The content of zinc in pure ashes stays close to the upper permitted limit value, or exceeds it but slightly.

Konin

The content of nitrogen (table 52) in yields of the first crop cut in 1977 (after 3 years of reclamation) fluctuated from 1.10 % (mix of grasses with legumes on plots fertilized with farm manure and NPK) to 2.14 % (mixture no. 4 on plots covered with 5 cm layer of fertile soil). This implies, that content of this component in the crops from Konin can be regarded as close to content of nitrogen found in plants grown on normal soils. Also the content of P_2O_5, within ranges from 0.26 percent, (mixture no. 2 and no 3 growing on control plots, and mixture no. 2 growing on plots fertilized with high moor peat and NPK) to 0.65 % (mixture no. 1 cultivated on plots fertilized with NPK) may be considered as satisfactory. Pure ash requires a supplement in fertilization of phosphorus. The content of K_2O fluctuates from 1.77 % (mixture no. 2 grown on plots supplied with 10 cm layer of fertile soil) to 2.87 % (mixture no. 3 growing on not fertilized control plots), which might indicate a moderate deficiency of this component in used cultivated soil to fertilize the ash. The potassic fertilization was restricted in the course of the field experiment due to a significant salinity of the not treated ashes. The content of CaO in yields of hay amounts from 0.53 % (mixture no. 3 - on plots fertilized with a 20 cm layer of fertile soil + NPK), to 2.60 % (mixture no. 3 - on control plots without fertilization used), speaking of sufficient reserves of this element in the fodder.

Regarding the contents of basic microelements one could state precisely the following regularities:

1) The content of boron exceeds often by several times the standards presented above for plants gathered from normal soils, achieving the 275 ppm B (mixture no. 1 grown on plot supplied with green manure and NPK) and 220 ppm (mixture no. 2 - on control plot); the results of boron designations speak of considerable effectiveness of fertilization with fertile soil:
   - the B content of 34 - 39 ppm by 20 cm thick layer of soil;
   - the B content of 50 - 62 ppm by 10 cm thick layer;
   - the B content of 61 - 108 ppm by 5 cm thick layer.
2) The content of copper in yields gathered from all plots is insufficient and amounts from 2.0 to 4.5 ppm.
3) The content of manganese conforms to standards stated for plants grown on normal soils.
4) The content of molybdenum approaches the 8.5 ppm value in crops of mixture no. 1 gathered from the control plot) other mixtures of grasses with legumes from this plot have also a raised Mo content; a high content of this element was also ascertained in mixture no.1, gathered from plots fertilized with NPK (5.75 ppm), and with high moor peat and NPK (4.90 ppm); the crops of these plants when

ASSESSMENT OF TREES AND SHRUBS' CULTIVATION SUCCESSFULNESS. HALEMBA

Table 55

Numbers of plots	Kind of culture	Method of pit dressing	Cuttings in years (spc.)				Losses in years (spc.)					Average increase in height (cm)			
			1975	1976	1977	Total	1975	1976	1977	Total	%	1975	1976	1977	in years 1975-77 (jointly)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I-1	Poplar I	1 a)	9	-	-	9	-	-	1	1	11,1	0,24	0,12	0,53	0,89
I-2	"	2 b)	9	-	-	9	-	-	-	-	0,0	0,21	0,08	0,19	0,48
I-3	"	3 c)	9	-	-	9	-	-	-	-	0,0	0,22	0,04	0,31	0,57
I-4	"	4 d)	9	-	-	9	-	-	1	1	11,1	0,21	0,11	0,24	0,56
II-1	Poplar II	1	9	-	-	9	-	-	-	-	0,0	0,24	0,24	0,36	0,74
II-2	"	2	9	1	1	11	1	1	-	2	22,2	0,23	0,15	0,17	0,55
II-3	"	3	9	-	-	9	-	-	1	1	11,1	0,20	0,19	0,29	0,68
II-4	"	4	9	2	-	11	2	-	-	2	22,2	0,23	0,19	0,42	0,84
III-1	Birch	1	24	23	-	47	21	2	18	41	87,2	0,19	-	0,12	0,31
III-2	"	2	24	24	-	48	24	-	17	41	85,4	.	-	0,23	0,23
III-3	"	3	24	24	-	48	22	2	20	44	91,7	0,06	-	0,22	0,28
III-4	"	4	24	24	-	48	23	1	19	43	89,6	0,09	-	0,27	0,36
IV-1	Gray alder	1	24	5	5	34	4	6	2	12	35,3	0,09	0,14	0,31	0,54
IV-2	" "	2	24	6	9	39	14	1	3	18	46,2	0,12	0,12	0,22	0,46
IV-3	" "	3	24	7	9	-	14	2	1	17	42,5	0,14	0,10	0,29	0,53
IV-4	" "	4	24	9	13	46	18	4	-	22	47,8	0,09	0,06	0,19	0,34
V-1	Black alder	1	24	23	-	47	5	18	5	28	59,6	0,14	.	0,15	0,29
V-2	" "	2	24	24	-	48	10	7	7	24	50,0	0,09	.	0,11	0,20
V-3	" "	3	24	15	-	39	6	9	10	25	64,1	0,15	0,40	0,32	0,87
V-4	" "	4	24	17	-	41	4	13	1	18	43,9	0,11	0,24	0,16	0,51
VI-1	Locust tree	1	24	-	-	24	-	-	-	-	0,0	0,78	0,42	1,02	2,22
VI-2	" "	2	24	1	-	25	1	-	-	1	4,0	0,63	0,45	0,99	2,07
VI-3	" "	3	24	-	-	24	-	-	-	-	0,0	0,68	0,50	0,98	2,16
VI-4	" "	4	24	-	-	24	-	-	-	-	0,0	0,56	0,37	1,09	2,02

Table 55 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VII-1	Larch	1	24	30	-	54	24	6	10	40	74,0	.	0,15	0,17	0,32
VII-2	"	2	24	32	-	56	24	6	6	36	64,3	.	0,14	0,13	0,27
VII-3	"	3	24	32	-	56	24	8	11	43	76,8	.	0,13	0,13	0,26
VII-4	"	4	24	36	-	60	24	12	9	45	75,0	.	0,14	0,13	0,27
VIII-1	Pea shrub	1	24	7	-	31	2	5	1	8	25,8	0,07	0,33	0,63	1,03
VIII-2	" "	2	24	5	-	29	1	4	-	5	17,2	0,11	0,33	0,71	1,15
VIII-3	" "	3	24	5	-	29	1	4	1	6	20,7	0,11	0,42	0,60	1,13
VIII-4	" "	4	24	11	-	35	-	11	2	13	37,1	0,06	0,25	0,49	0,80
IX-1	Willow	1	24	8	-	32	6	2	-	8	25,0	0,13	0,07	0,23	0,43
IX-2	"	2	24	9	-	33	8	1	1	10	30,3	0,12	0,03	0,15	0,30
IX-3	"	3	24	6	-	30	3	3	-	6	20,0	0,06	0,04	0,15	0,25
IX-4	"	4	24	12	-	36	7	5	-	12	33,3	0,10	0,05	0,20	0,35
X-1	Willow shoot cuttings	1	48	-	32	80	-	32	14	46	57,5	-	0,31	0,13	0,44
X-2	" " "	2	48	-	42	90	-	42	15	57	63,3	-	0,10	0,14	0,24
X-3	" " "	3	48	-	45	93	-	45	18	63	67,7	-	0,09	0,06	0,15
X-4	" " "	4	48	-	47	95	-	47	22	69	72,6	-	.	0,05	0,05
XI-1	Poplar shoot cuttings	1	48	-	36	84	36	-	29	65	77,4	-	0,36	0,12	0,48
XI-2		2	48	-	37	85	37	-	15	52	61,2	-	0,18	0,11	0,29
XI-3		3	48	-	29	77	29	-	29	58	75,3	-	0,23	0,46	0,69
XI-4		4	48	-	22	70	22	-	15	37	52,9	-	0,13	0,14	0,27

Explanation to col. 3:

a) pits dressed with ash + fertile soil + NPK
b) pits dressed with ash + bentonite + NPK
c) pits dressed with ash + mountain peat + NPK
d) pits dressed with ash + NPK

consumed in greater quantities may induce molybdenum illness in cattle;

5) The content of zinc seems to be insufficient as opposed to yields from Halemba, for it does not exceed the 20.5 ppm;

6) The content of iron is much lower than in yields from Halemba, in some samples however is much higher than in plants gathered from cultivated soils;

7) The content of cobalt in crops of plants grcwn on plain ash exceeds the quoted above levels only to a small degree, one cannot therefore regard these crops as toxic to cattle.

Summarizing one may state, that the crops of plants cultivated on the Konin Power Plant disposal stacks may be consumed by cattle after cheking if the norm of molybdenum content is not exceeded. One should continue the investigations of effects of excessive amounts of boron in plants liking boron, on animals fed with such plants.

Value of nourishment

Nutrient value of gathered crops was determined by laboratory methods through designations of the protein and ash contents and also on the basis of macro and microelements content (table 51 and 52) In Poland is accepted, that grasses may contain on average 7.67 percent raw protein (maximally 12.8 %) and 5.90 % of ash (maximally 8.5 %) and pulse crops respectively 18.0 % (maximally 22.7 %) of protein, and 6.75 % (maximally 8.05 %) of ash. The usefulness of obtained fodder for consumption by animals was discussed above

Halemba

Most protein (17.5 %) contained mixture of grasses (no. 2) collected from plots fertilized with bentonite and NPK. The lowest protein content had mixtures gathered from control plots (10.0 - 15.8 %), however it was high enough still, and indicated a high nutrient value.

Content of ash was the highest in mixtures of grasses with legumes collected from plots fertilized with double N2PK dose rate (9.12 %). With a small ash content (under 5 %) distinguishes itself mixture of grasses (no. 2) collected from plots fertilized with fertile soil + NPK, and mixture of legumes with orchard grass (no. 3), gathered from plots fertilized with fertile soil + NPK. No correlation between the method of ash melioration and the ash content in crops was ascertained.

Summing up one can state, that crops of grasses and legumes from Halemba have a high nutrient value, however are not fit to be consumed by animals in greater quantities due to an increased content in some samples of zinc and molybdenum.

Konin

The content of raw protein below 7.67 % level was not encountered. Similarly no reserves of protein above the 18.0 % level were found. One may assume, that the acquired crops average in the protein reserves, whereby no direct relationship of the protain reserves to the method of the ash "soil" melioration was established. The content of ash in plants is low as rule, and only in some cases exceeds the 5.90 % level. Large amounts of ash contain crops of the mixture no.3 (lucerne and orchard grass) gathered from plots without fertilization. Ash fertilized with fertile soil giving crops with lesser ash content.

In summary one may say, that the highest nutrient values possess grass mixtures gathered from plots fertilized with organic substances provided these contain no excessive amounts of harmful to animals molybdenum. Highest reserve of protein distinguishes the mixture no. 3 (lucerne and orchard grass).

Radiactivity

Measurements of radioactivity performed on harvested vegetation are presented in tables 53 and 54andwas determined that the beta radioactivity of hay samples (per unit of fresh mass) was less than the established standards (30 pCi/g of fresh mass). The highest activity occurred in vegetation collected in Halemba from plots covered with soil, and from plots treated with farm manure. The beta activity comes principally from the natural potassium radioisotope ^{40}K.

The content alpha radioactivity per unit green mass ranged between:
- 3.02 to 17.64 pCi/g for vegetation collected at Halemba;
- and from 1.98 to 27.09 pCi/g at Konin.

This indicates the ability of radioisotope concentration in the grasses. Insufficient data are available to determine whether the grasses also concentrate alpha activity.

The highest gamma activity was measured in crops grown on the plots at Halemba covered with soil or treated with farm manure (similar to alpha activity.

THE GROWTH OF TREES AND SHRUBS

Method of assessment

As criteria to assess the vigor and growth of trees and shrubs, the following observations were made:

a) the survival of particular species;

b) increases in height.

In the spring (May) and in autumn (September) quantitative inventories were performed for all living specimens. In cases when the specimen had dead corona but living side shoots, the height was measured in relation to the shoot. Simultaneous analysis of the health of the species was performed. Results of measurements are presented in tables 55 and 56.

Halemba

Statistical analysis showed that survival of species was not affected by the method of treating the planting pit. For example, losses of cuttings were lowest on plots treated with soil the first year but losses were among the highest in the second year.

However, the differentiation in survival of particular species was quite evident.
The highest rate of survival occurred for locust tree, Siberian pea shrub, and poplar trees.
A moderate survival rate was measured for willow, black alder and European larch.
The lowest survival rate occurred for gray alder and birch.

The rate of survival (and the growth) is influenced by climatic conditions, atmospheric pollution and illnesses. About 90 percent of trees have on their butt swellings frost ribs. Airborne compounds of fluorine had an adverse impact on birch at Halemba while SO_2 adversely affected gray alder. Gray alder had some beetle damage and several specimens withered as a result of worm (cimbex) damage. Fungi were numerous and they can also cause cuttings to die. Root zone cultures isolated on artificial substrates with nutrients produced Fusarium sp., numerous saprophytic soil species of Glicoladium roseum, and a number, of species of Penicillium, Aspergillus Alternaria and Trichoderma. Nectria cinnabarina and Nectria dittisima were found on locust trees. Where no industrial air pollution is evident these are only present as saprophytic fungi, however at Halemba they appear in force on all living specimens. Willow contained Cryptodiaporthe salicina (Discella carbonacea in sex stage) - this fungus causes, in birch family a bark scorch and kills shoots. During the early autumn, alder leaves showed the typical symptoms of SO_2 damage as well as a number of saprophytic fungi in injuries of abiotic nature. Cladosporium herbarum Linc., Alternaria tenuis Noes, Stemphylium sp., were especially numerous. By the end of the growth period, the internerve area of gray alder leaves contained typically ginger-brown stains, which

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K O N I N

Table 56

Numbers of plots	Kind of culture	Method of pit dressing	Cuttings in years (spc.)				Losses in years (spc.)					Average increase in height (cm)			
			1975	1976	1977	Total	1975	1976	1977	Total	%	1975	1976	1977	in years 1975-77 (jointly)
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
I-1	Poplar I	1a)	9	9	-	18	8	1	3	12	66.7	-	-	0.12	0.12
I-2	"	2b)	9	9	-	18	2	7	-	9	50.0	-	0.20	0.16	0.36
I-3	"	3c)	9	9	-	18	4	5	-	9	50.0	-	-	0.15	0.15
I-4	"	4d)	9	9	-	18	7	2	-	9	50.0	-	-	0.21	0.21
I-5	"	5e)	-	9	-	9	-	-	-	-	0.0	-	0.34	0.27	0.61
II-1	Poplar II	1	9	9	-	18	8	1	4	13	72.2	-	-	0.03	0.03
II-2	"	2	9	9	-	18	7	2	-	9	50.0	-	0.13	0.11	0.24
II-3	"	3	9	9	-	18	5	4	1	10	55,6	-	0.19	0.16	0.35
II-4	"	4	9	9	-	18	7	2	-	9	50.0	-	0.52	0.17	0.69
II-5	"	5	-	9	-	9	-	-	1	1	11,1	-	0.07	0.19	0.26
III-1	Birch tree	1	20	39	-	59	20	19	1	40	67,8	-	-	0.28	0.28
III-2	"	2	20	40	-	60	20	20	-	40	66.7	-	-	0.22	0.22
III-3	"	3	20	38	-	58	20	18	1	39	67,2	-	0.09	0.18	0.27
III-4	"	4	20	38	-	58	20	18	-	38	65,5	-	0.17	0.21	0.38
III-5	"	5	-	36	-	36	-	16	-	16	44,4	-	0.19	0.47	0.66
IV-1	Gray alder	1	20	30	-	50	20	10	1	31	62,0	-	0.11	0.12	0.2
IV-2	" "	2	20	26	-	46	20	6	1	27	58.7	-	0.16	0.15	0.
IV-3	" "	3	20	27	-	47	20	7	2	29	61.7	-	0.11	0.14	0.25
IV-4	" "	4	20	22	-	42	20	2	-	22	52,4	-	0.19	0.28	0.47
IV-5	" "	5	-	20	-	20	-	-	-	-	0.0	-	0.29	0.60	0.89
V-1	Black alder	1	20	40	-	60	20	20	1	41	68.3	-	-	0.32	0.32
V-2	" "	2	20	33	-	53	20	13	-	33	62.3	-	0.23	0.38	0.61
V-3	" "	3	20	38	-	58	20	18	1	39	67.2	-	0.09	0.15	0.24
V-4	" "	4	20	35	-	55	20	15	1	36	65.5	-	0.10	0.11	0.21
V-5	" "	5	-	28	-	28	-	8	-	8	28.6	-	0.11	0.26	0.37

Table 56 continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
VI-1	Locust tree	1	20	33	-	53	20	13	3	42	79.2	-	0.27	0.33	0.60
VI-2	" "	2	20	21	-	41	20	1	7	29	70.7	-	0.13	0.54	0.67
VI-3	" "	3	20	24	-	44	20	4	1	25	56.8	-	0.20	0.45	0.65
VI-4	" "	4	20	21	-	41	20	1	3	24	58.5	-	0.13	0.44	0.57
VI-5	" "	5	-	23	-	23	-	3	3	6	26.1	-	0.27	0.41	0.68
VII-1	Caspian willow	1	20	31	-	51	20	11	1	32	62.7	-	0.29	0.45	0.74
VII-2	" "	2	20	30	-	50	20	10	-	30	60.0	-	0.43	0.60	1.03
VII-3	" "	3	20	37	-	57	20	17	-	37	64.9	-	0.32	0.57	0.90
VII-4	" "	4	20	29	-	49	20	9	-	29	59.2	-	0.55	0.54	1.09
VII-5	" "	5	-	20	-	20	-	-	-	-	0.0	-	1.08	0.64	1.72
VIII-1	Sea buckthorn	1	20	35	-	55	20	15	2	37	67.3	-	0.14	0.11	0.25
VIII-2	" "	2	20	32	-	52	20	12	2	34	65.4	-	0.06	0.19	0.25
VIII-3	" "	3	20	29	-	49	20	9	-	29	59.2	-	0.08	0.27	0.75
VIII-4	" "	4	20	30	-	50	20	10	4	34	68.0	-	0.06	0.21	0.27
VIII-5	" "	5	-	24	-	24	-	4	-	4	16.7	-	0.09	0.24	0.27
IX-1	Siberian pea shrub	1	20	24	-	44	20	4	4	28	63.6	-	0.02	0.12	0.14
IX-2	" " "	2	20	30	-	50	20	10	5	35	70.0	-	0.04	0.02	0.06
IX-3	" " "	3	20	34	-	54	20	14	2	36	54.0	-	0.02	0.11	0.13
IX-4	" " "	4	20	31	-	51	20	11	1	32	62.7	-	0.01	0.04	0.05
IX-5	" " "	5	-	21	-	21	-	1	1	2	9.5	-	0.02	0.26	0.28
X-1	Poplar shoot cuttings	1	40	18	-	58	18	-	17	35	60.3	-	0.50	0.31	0.81
X-2	" " "	2	40	57	-	97	35	22	13	70	72.2	-	0.59	0.12	0.71
X-3	" " "	3	40	65	-	105	35	30	5	70	66.7	-	0.18	0.04	0.22
X-4	" " "	4	40	54	-	94	30	24	1	55	58.5	-	0.18	0.09	0.27
XI-1	European larch	1	-	20	20	40	-	20	1	21	52.5	-	-	0.11	0.11
XI-2	" "	2	-	20	20	40	-	20	-	20	50.0	-	-	0.15	0.15

Table 5c continuation

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
XI-3	European larch	3	-	20	20	40	-	20	1	21	52.5	-	-	0.10	0.10
XI-4	" "	4	-	20	20	40	-	20	4	24	60.0	-	-	0.10	0.10
XI-5	" "	5	-	20	20	40	-	20	1	21	32.5	-	-	0.10	0.10

Explanation to col. 3:

a) pits dressed with ash + fertile soil + NPK
b) pits dressed with ash + bentonite + NPK
c) pits dressed with ash + mountain peat + NPK
d) pits dressed with ash + NPK
e) pits dressed with soil + NPK

are normally caused by a shortage of calcium. Infection of withered branches with Diaporther sp. and Nectria cinnabarina fungi followed for the second time. Rabbits also caused damage to and affected the survival of cuttings despite the use of a wirenet fence. Attempts to wrap the stem of cuttings with foil were not satisfactory.

The greatest growth increment was displayed by locust trees (to 1.20 m in the first year, and up to 0.80 m in the second year (table 55). Pea shrub did not show marked increases until the third year. Poplars showed very slender increases in height. Decreases in growth in the second and third year indicate a maladjustment to the growth conditions.

After 3 years of the tree and shrub cultivation it can be stated, that slightly higher increases in height were achieved in combinations of pits filled with ash, fertile soil, and industrial fertilizer mixtures. Smallest increases gave combinations with bentonite or high moor peat dressing the pits.

The causes of unsatisfactory increases and of many losses of cuttings are ascribed to the unfavourable habitat conditions (lack of suitable soil, atmospheric air pollution with SO_2 and F_2 and dust, the shortage of water during the critical for the cuttings periods), promoting the diseases.

Konin

Statistical analysis indicated that on the experimental field in Konin there were significant differences in plant response to the treatment methods used to prepare the ash.
The survival ability of species is grouped into three categories according to the survival rate as follows:
- highest survival rate: gray alder, locust tree, Siberian pea shrub
- average survival rate: sea buckthorn, poplar, Caspian willow
- low survival rate: black alder, white birch, European larch.

Dependent on the method of treating the pits in planting, positive results were achieved with pits filled with soil. Mixtures of ash with fertile soil also support good growth. Usatisfactory growth was achieved in the other three treatments. In the first year alomost all cuttings were lost (table 56), (explained by insufficient atmospheric precipitation, by drought intensified by loosened material during blasting, and by salinity of the ashes /full dressing of pits with fertile soil was applied only in the second year/). In the second and third year the losses at Konin were explained, as at Halemba, as due to a strongly toxic "soil" environment, atmospheric pollution, and abiotic impariments. Rabbits also ate shoots of pea shrub, willow, poplar, locust tree and gray alder which affected not only the survival of these species but also resulted in poorer development. The influence of industrial emmissions (fluorine and SO_2) was evident.

Injuries were caused to willow by the feeding cockchafer (Lamia textor), and under the bark of willow and alder by the feeding larvae (Cryptorhynchus lapathe). These insects did not kill cutlings. They rather colonized on dead material. No appearance of pathogenic fungi was found on larch, alder, pea shrub sea buckthorn, and birch tree that could in a substantial way contribute to withering. The root zones of withered cuttings did contain Fusarium sp, and numerous saprophytic soil species such as Gliocladium roseum, Penicillium, Aspergillus, and Altenaria.

The highest annual increases were not as high as that occurring under normal soil conditions. Locust tree and pea shrub which showed large growth at Halemba, showed lighter growth at Konin. Caspian willow produced the greatest increase in growth (1.08 m growing in pits with soil). Poplar development was considered moderate in pits filled with soil.

In summary, the experiments with trees and bushes at Konin did not provide a solution to the problem of forest reclamation for these ashes. The failure is attributed to toxic subsoil though some mitigation of toxicity was provided by the soil treatments. Atmospheric pollution

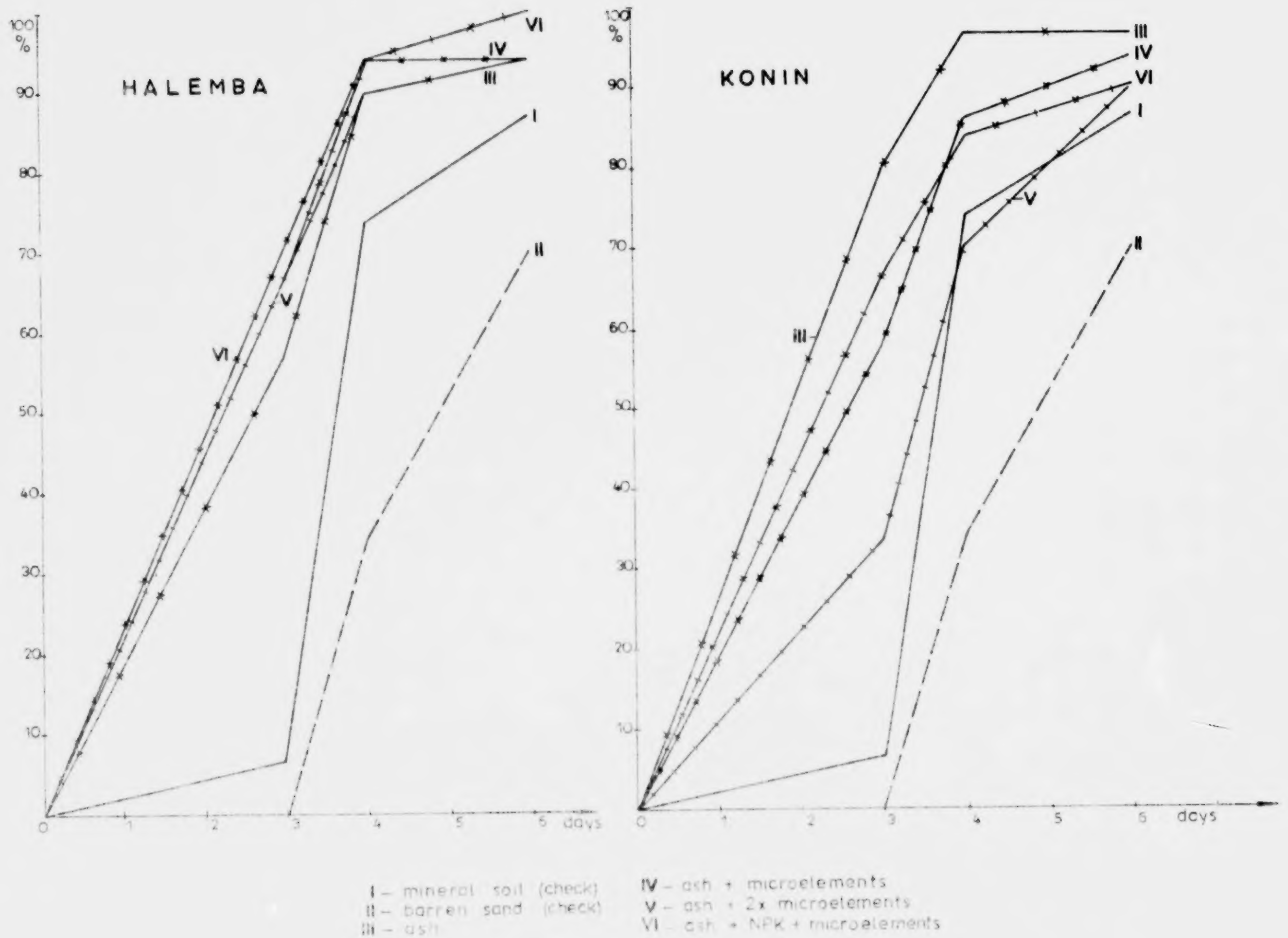

Fig. no. 28. Dependence of plant seedlings on mineral fertilization of ashes.

with fluorine and SO_2 and the low precipitation also contributed to failures. The weakened cuttings were then susceptible to bacterial disease and predators.

While the treatments with soil did not bring the expected results, further tests could be performed after a removal or limitation of atmospheric pollution from the nearby power plant and aluminium works, or after first reclaiming with grasses and forbs to reduce soil toxicity and then planting shrubs and trees.

SECTION 9

ASSESSMENT OF RESEARCH RESULTS

THE UTILITY OF THE RECLAIMED ASHES

The ashes investigated from bituminous coal or lignite, have one particular characteristic in common, they are strongly alkaline (pH from 11.5 to 12.8). The causes of alkalinity do differ between the two. Ash from bituminous coal is alkaline because of a high sodium chloride content. Ash from lignite also contains significant quantities (up tc 34 %) of calcium and magnesium oxides.

Plants cultivated under Polands climate are usually best suited for soil pH of from 5.6 to 7.0. Only a few plants (e.g. selected species of forbs) tolerate conditions up to 8.2 pH. At pH values of 7 to 8 many necessary elements for the plants (e.g. iron, manganese, zinc, copper, cobalt) pass into forms that are difficult for plants to assimilate. Conversely the assimilability of molybdenum increases gradually with a rise in pH. This leads to excessive concentration of this element in crops, which in turn can cause a molybdenum illness in farm animals. The pH has an interesting influence on the assimilation of phosphorous. Phosphorous is, as a rule, difficult to dissolve. It dissolves best at the pH 6.5. Thus in alkaline conditions, the plants often die out due to a phosphorus deficiency. At pH's above 9 calcium and magnesium become unavailable to plants. Insoluble compounds such as calcium phosphate are formed in the soil. Furthermore, in alkaline conditions, algae and nodule bacteria do not form.

Ashes disposed off hydraulically in sedimentation basins do lose some alkalinity (to 8.5 - 9.5) but even in such conditions the vegetation cannot develop.

Ashes collected after burning lignite contain more than 9 g NaCl per 1 dm^3 which in gravimetric conversion amounts to about 2 percent of the ash mass. Ashes from bituminous coal are less saline, they have about 1 percent NaCl. In Poland most situations in NaCl concentrations above 0.02 percent has an adverse effect on woody vegetation (e.g., apple trees, cherries, pear trees, lime trees, chestnut trees, fruit trees). On these saline soils deciduous species can grow only with extensive watering. Soils containing 0.3 to 0.6 percent of dissolved salts are considered weakly saline. Soils containing more than 1.5 percent of these salts are considered excessively saline. Using these limits as a guide the ashes from Konin lignite should be regarded as excessively saline, and ashes from Halemba bituminous coal belong to the average salinity category.

The ashes under study show satisfactory reserves of plant-available potassium (9.5 - 13.0 mg of K_20/100 g of ash from Konin and 13.5 - 25 mg of K_20/100 g of ash from Halemba). Such reserves are characteristic of highly fertile soils. Phosphorus concentrations in fresh ashes from Halemba are very high (80 - 175 mg of P_20/100 g). They are, however, not available to the plants. The ash from Konin is exceptionally deficient in phosphorus.

The ash from Halemba has significant reserves of magnesium (15 - 45 mg mg/100 g of ash); the ash from Konin contains insufficient quantities (0 - 1.2 mg of mg/100 g). Both types of ashes contain insufficient reserves of nitrogen and of such microelements as Cu and Zn for satisfactory plant growth. Manganese occurs in moderate concentration (370 - 540 ppm in bituminous coal ashes from Halemba and in high concentration (2100 - 4000 ppm) in lignite ashes from Konin). It is, however, not available to plants in the alkaline conditions of the ash.

A separate problem is the moderately high concentration of water - soluble boron (bituminous coal: 7 - 15 ppm; lignite: 8 - 33.5 ppm).

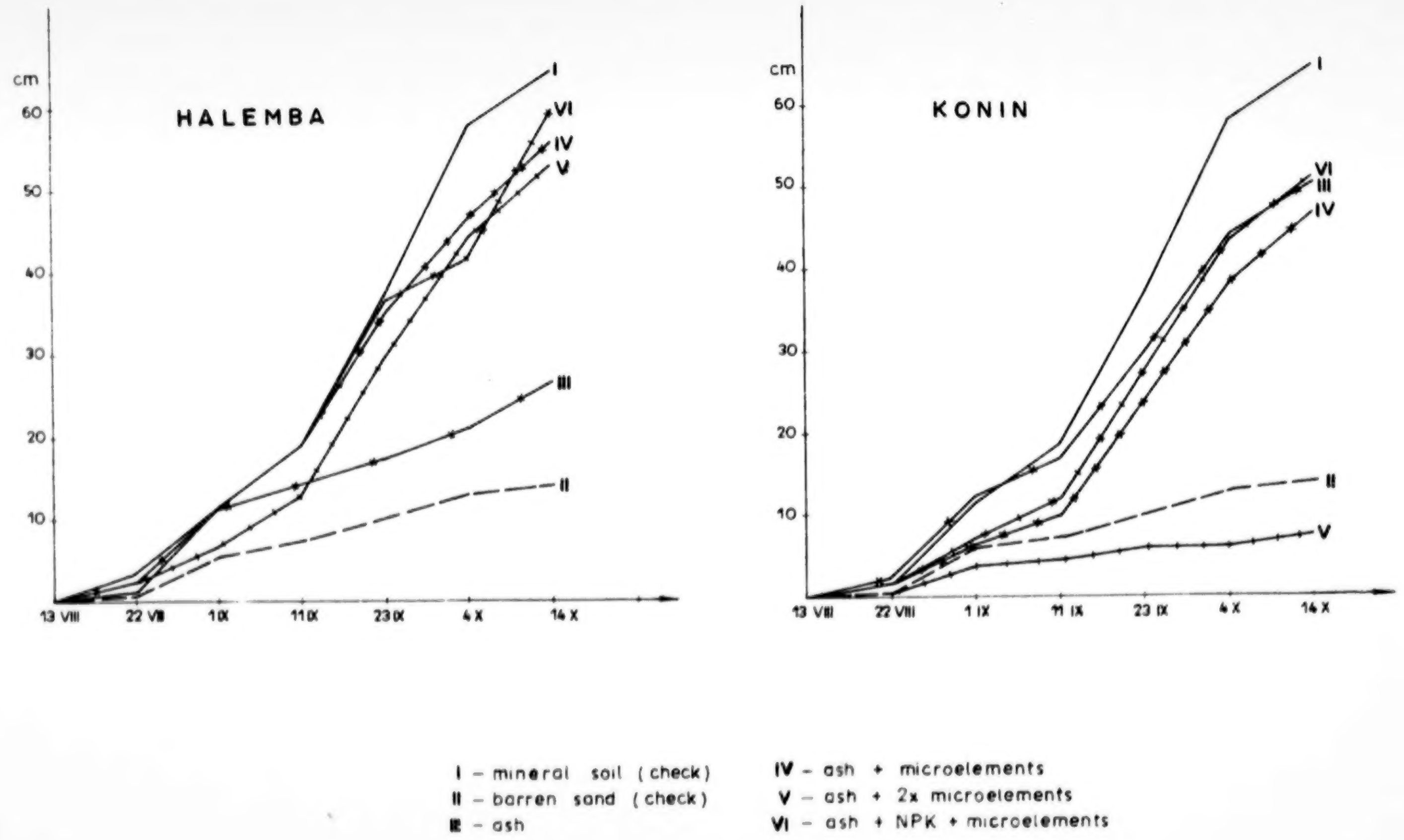

Fig. no. 29. Dynamics of white mustard growth on ashes in greenhouse experiment.

Boron concentrations above 10 ppm are considered harmful to the growth of plants. Molybdenum, cobalt, selenium and cadmium concentrations do not exceed the accepted qualitative standards for fertile soils.

Investigations also included determinations of the radioactivity of ashes. The specific alpha and gamma radioactivity of the ashes was at least 2.5 times higher than in normal soil. In the case of the bituminous coal ashes, the alpha activity was up to 10 times higher and the gamma activity was up to 6.5 times higher. While such values are not harmful to humans or animals in the sense of direct danger from ionizing radiation, the potential for accumulation of radioactivity in crops points to a necessity for concern. Migration of ^{226}Ra through water is one mechanism that could lead to concentration. The specific beta activity in all investigated cases was within relevant standards. This activity is attributed in large part to the natural isotope of potassium ^{40}K.

Fly ash collected in electrostatic precipitators usually does not contain many particles larger than 1 mm. The main component is dust-sized material with diameters of 0.1 to 0.02 mm (averages 81 percent in lignite ashes from Konin, and 59 percent in bituminous coal ashes from Halemba). Colloidal clay material does not exceed 4 percent. Material with such a granulometric composition is usually characterized with high permeability and a vulnerability to water and air erosion. The ash, once it is deposited in the sedimentation basins, is also characterized with high porosity (approaching 72 percent volumetrically). This material also has a high permeability, a low field and capillary water capacity, is easily eroded by wind.

These properties of ashes determine that agricultural or silvicultural utilization of the materials is not possible without adequate preparation.

Lignite ashes from the regions of Konin contain significant quantities of calcium (up to 34 percent of CaO). For this reason some research workers recommend their utilization in fertilization of arable land. This use can be considered only in reference to heavy soils requiring liming with calcium oxide and not with calcium carbonate - and might

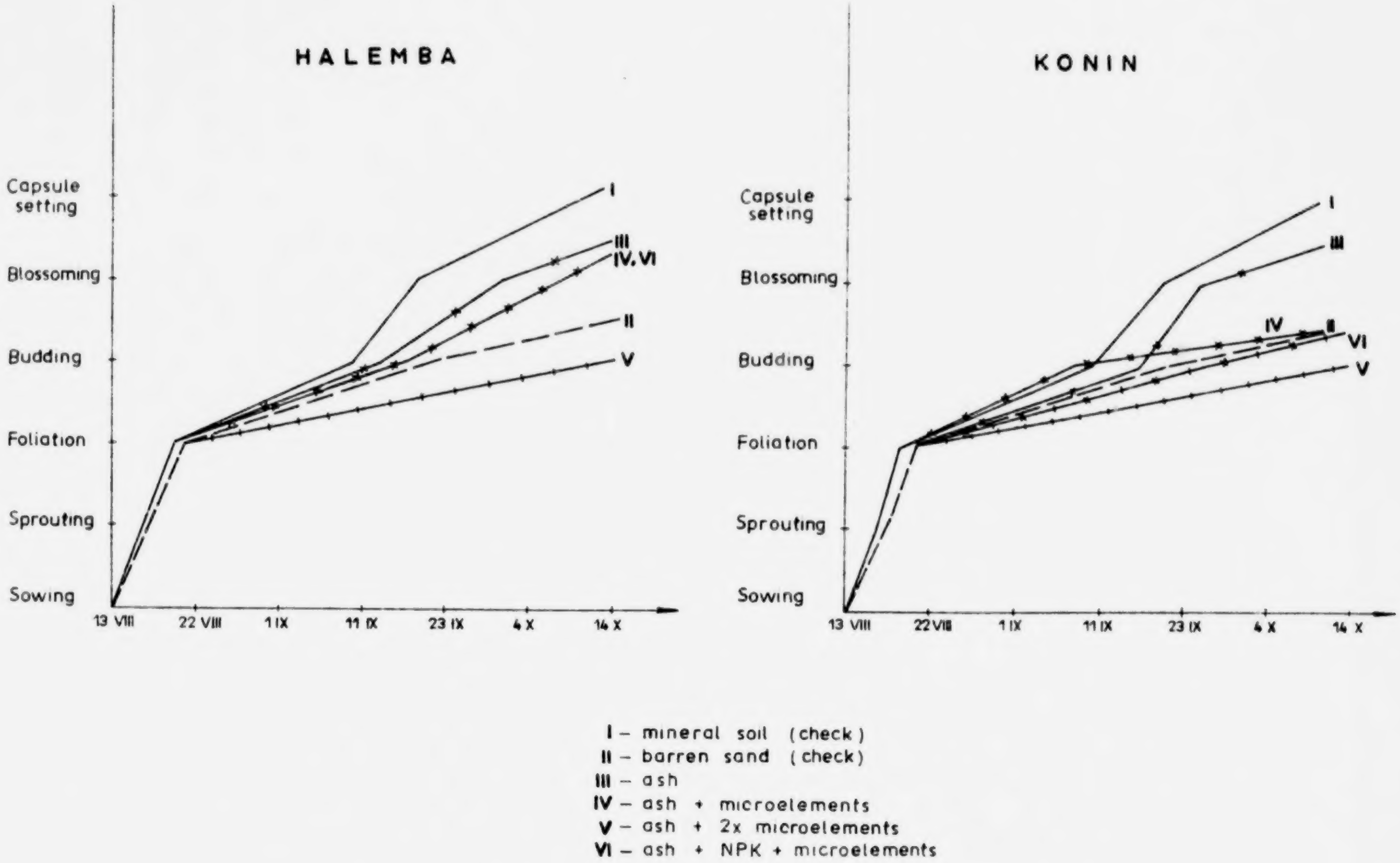

Fig. no. 30. Development phases of white mustard (Synapis alba) in greenhouse experiment.

be done only where use of the ashes, with the detritus that accompanies the calcium in the ash, is economic because of lack of naturally-occurring calcium.

HYDRAULIC SLUICING OF ASHES AND THE RECLAMATION REQUIREMENTS FOR WASTE MATERIAL

Analytical tests have shown that essential changes in the properties of ashes (properties important for reclamation) occur during hydraulic transportation to and settling in the sedimentation basins.

As previously mentioned pH is lowered. This change is explained by a leaching of sodium hydroxide. A high pH is usually caused by hydrolysis of sodium carbonate:

$$2Na^+ + CO_3^{2-} + 2H_{2}0 \rightleftharpoons 2Na^+ + 2OH^- + H_2CO_3$$

Ions of OH^- are giving pH 10 and higher. The sodium complex undergoes hydrolysis:

$$Na \boxed{micelle} + HoH \rightleftharpoons H \boxed{micelle} + Na^+ + OH^-.$$

As the NaOH dissociates to greater extent than the weak H_aCO_3, a prevalence of OH^- ions occurs. The effect of leaching ashes in the process of hydraulic transportation is to cause a loss of sodium (sodium hydroxide) and a decrease in the quantity of OH^- ions. Further decrease of the pH would require additional leaching of the ashes with water. The degree of leaching depends on the salt content of the reused water. If an "open" system of water sluicing is used, where fresh water is added in large amounts, the leaching will be greater than in a closed cycle where water is reused.

The process of leaching salts can be traced by periodic measurements of electric conduction of water in contact with the ashes. (fig. 36).

Fresh fly ash from the electrostatic precipitators produced the highest electrical conductivity in the first 2 to 8 hours of leaching. Then the electrical conductivity drops. Samples of ashes taken from the sedimentation basin produced a continuing increase in electric conduction. During a 192 hour period of leaching, fresh ashes from the electrostatic precipitators produced 751 mg and 2960 mg (per kg of ash) or soluble salts for Halemba and Konin, respectively. Ashes collected from the sedimentation basins produced 203 and 1740 mg respectively.

It is stressed that during transport and settling of the ash, potentially toxic substances such as sodium and boron are leached from the ashes. For example, in samples of ash from Halemba, after an 8-day leaching, 1 kg of fresh ash (from electrofilters) produced 0.153 mg of boron and 53.21 mg of sodium, whereas samples from sedimentation basins produced only 0.058 mg of boron and 2.87 mg of sodium.

The process of hydraulic sluicing also reduces the radioactivity of the ashes. For example, fresh ash from electrostatic precipitators at the Halemba Power Plant produced alpha, beta and gamma, activities of 499.5, 34.6 and 385.6 pCi/dm^3 respectively, while leachate of ashes collected from the sedimentation basin contained decreased levels of 83.3, 0.0, and 60.0 pCi/dm^3 respectively.

Thus the hydraulic sluicing process improves the condition of the ash insofar as vegetative reclamation is concerned. However, concern as to the fate of the leached substances must remain.

PROVISION OF ASH DISPOSAL STACKS AGAINST REPEATED WIND EROSION

It was belived that stabilization of the waste ash against wind erosion could be achieved between the period of initial cultivation and establishment of vegetation through the application of chemical compounds. It was envisioned that such materials would not adversely affect vegetation.

However, tests performed using the latex compound LBSK-5545 on those plots seeded with grass over a two year period indicated that the issue was more complex than first thought.

The effect of application of latex at two rates (0.10 and 0.20 mm) was to create a stromg elastic layer which effectively protected against erosion. High rates of seeding (164 kg/ha grasses and 84 kg/ha alfalfa) produced dense stands of vegetation the first year. Only the first harvest of green mass during the second year of the experiment showed distinguishable differences in yields. In these harvests it appeared that grasses reacted positively to latex treatment giving 32 percent higher yield than on control plots. Increase in the rate of latex application from 0.10 to 0.20 mm caused an insignificant decrease in crop yield.

On plots planted with alfalfa the response was different. Here the application of the smaller amount of latex (0.10 mm) caused a reduction in crop yield by 13 percent and the larger rate (0.20 mm) provided a decrease as much as 51 percent.

The tests suggest that for best revegetation, a rather thin latex layer on the order of the 0.10 mm (0.10 dm^3/m^2) diluted with water 1:10 or greater is desirable. Greater dilution will likely provide deeper bonding of the near - surface layer of ash. The latex covering protects ash in sufficient manner against it blowing away until the time this function is taken over by herbaceous vegetation.

TREATMENT OF ASHES

Even after the reduction in alkalinity resulting from hydraulic sluicing, the ashes still are not suited for supporting vegetation.

Treatment of the ashes therefore designed to:

a) decrease the alkalinity to slighty acid or neutral conditions

b) decrease in salinity to the limits recognized as harmless for the majority of desirable plants

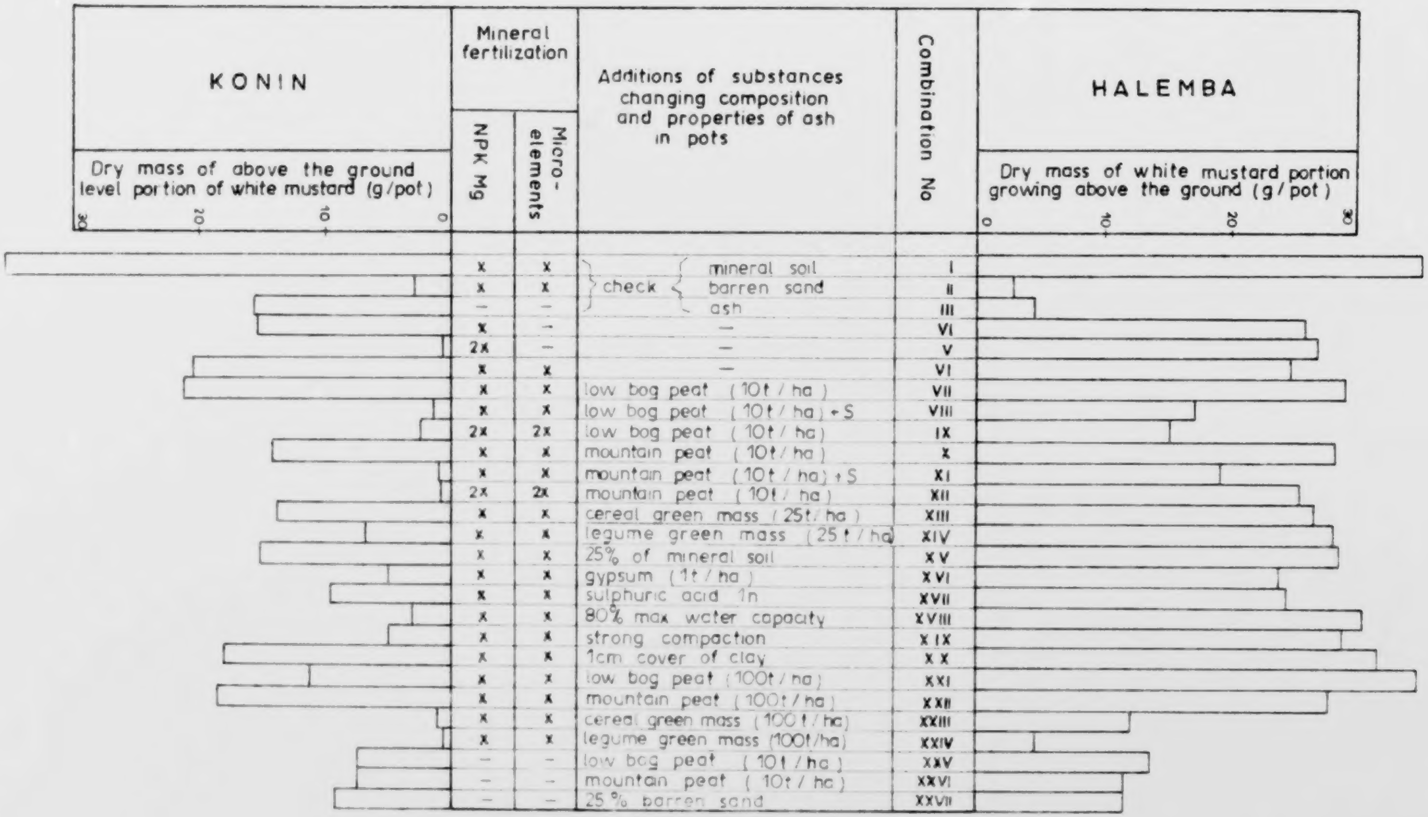

Fig. no. 31. Results of greenhouse experiment with cultivation of white mustard on ashes (I series). Harvest of dry mass.

c) decrease in the concentration of ionizing substances such that the crops would be harmless for human and animal consumption

d) increase the availability of macro and microelements contained in ashes to plants through conversion of forms or through creation of environmental conditions in which these components would be available

e) maintain the supply of nutrient components for plants at optimal quantities

f) improvement of physical, air-water, sorptive, and biochemial properties of ashes to afford optimal soil producing processes.

The principal objective was to reduce the pH. Greenhouse experiments showed that treatment with flowers of sulphur, gypsum, and sulphuric acid did not increase vegetative yields. Acidification with peat did not result in satisfactory vegetative yields either.
While treatments with peat and manure, as well as with soils and sand, reduced the pH, there was not a consistent increase in vegetation yields. This indicates that more variables than pH affected vegetation success.

The measurement of salinity of the treated ash provided indications of the dependence of the salinity (NaCl) level on the type of treatment. As emphasized already, the most effective method of reducing content of dissolved salts in water remained the process of hydraulic sluicing with water. Due to a shortage of irrigation water, was viewed as a source of leach water to be used to reduce salt contents. To enhance infiltration and leaching, the ashes were loosened and deep tilled. The effect of these treatments was to reduce the salinity in Konin from over 9 g/dm^3 to 2.67 to 3.63 g/dm^3, and in Halemba from 2.97 to 5.10 g/dm^3 to 0.69 to 0.89 g/dm^3. Further reductions in salinity were obtained through addition of soils, sand and peat. It was found that salinity of a mixture of ash and soil decreases in inverse proportion to the thickness of soil layer. Peats and farm manure reduce salinity to a smaller degree. Intensive fertilization with nitrogen and phosphorus produces slight increases in salinity. Addition of bentonite did not affect salinity.

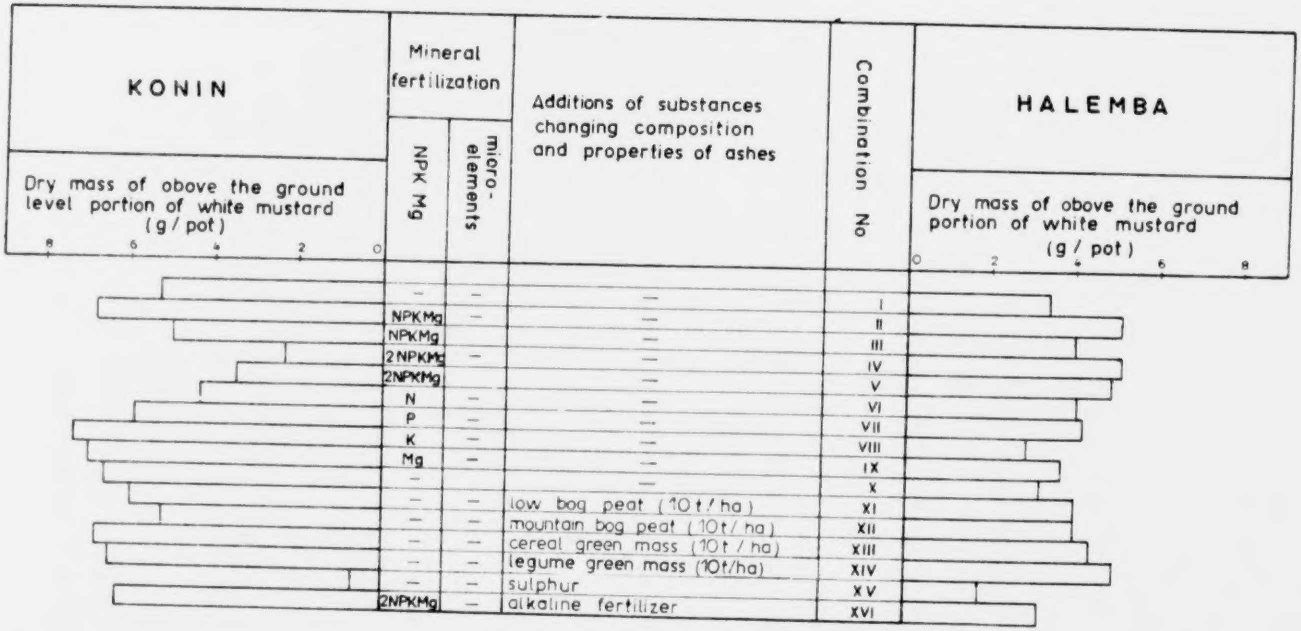

Fig. no. 32. Tests of greenhouse experiment with white mustard cultivation on ashes (II series) - collection of dry mass.

During the three years of field investigations a gradual reduction in salinity was observed.

Boron concentrations were also reduced along with salinity. Changes in the boron concentrations were not consistent over time since content of boron increased in subsequent time periods, probably as a result of chemical reactions in which boron passes from insoluble to soluble forms. The plants intensively assimilate boron such that a correlation exists between the boron concentration in the subsoil and concentrations in plants. Plants growing in a treatment with high boron concentrations (29.3 ppm B) contained 212 ppm B (alfalfa and orchard grass). While the bituminous coal ashes studied at Halemba contained much smaller amounts of boron, the vegetation uptake was also higher in 1976 than in 1977.

The positive effect of fertilization on the vegetation was predictable. The greenhouse experiments (fig. 28) showed the dependence of plant germination on the type of fertilization. These experiments showed that increased fertilization retarded germination. Macroelements had a greater influence than microelements. The dynamics of growth depended both on the type and on the application rate of fertilization, and the dynamics differed for different types of ashes. Additions of NPK to lignite ash caused an increase in growth of the test vegetation (fig. 29) whereas addition of microelements acted in the reverse. Larger doses of micrcelements caused a "poisoning" of the ash-soil medium and a rapid decrease in crop yields. Increases in fertilization of bituminous coal ash caused an increase in growth. These interrelations were confirmed in field experiments. Field fertilization with both macro- and microelements caused delays in plant development (fig. 30). In Konin a delay in budding, in flowering and capsule formation was also caused by macroelements.

The addition of soil, bentonite, peat, or manure to the ash to provide a suitable growth medium produced more positive results. Field experiments confirmed the dependence of vegetation on the physico - chemical changes produced in ash by adding soil. In previous experiments carried out by other research workers, publications [3, 10, 16,

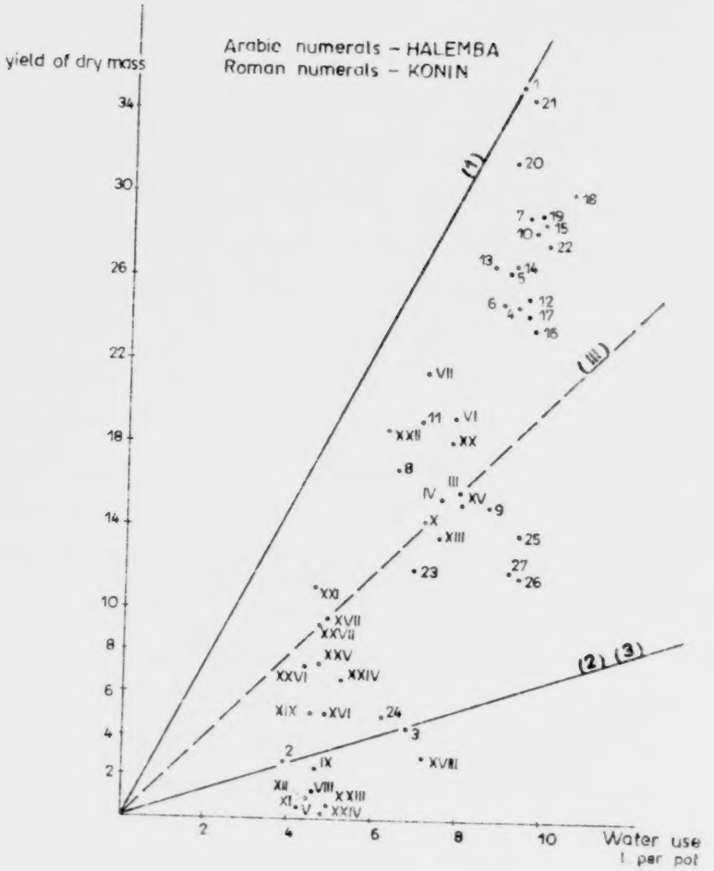

Fig. no. 33. Correlation of yields and water consumption by white mustard in greenhouse experiments.

17, 18]. A thick layer of soil, (0.20 m, 0.50 m thick, and thicker) was applied. The crops depended almost exclusively on the fertility of the soil. In this research the goal was also to check the effectiveness of ash treatment with smaller quantities of soil. By 1976 field experiments indicated the following correlation of crop yields with the thickness of fertile soil (grass seed mixture):

	Lyer of fertile soil			
	20 cm	10 cm	5 cm	0(control)
	crop yield (t/ha)			
Halemba	6.20	3.56	2.55	2.07
Konin	5.10	4.83	4.25	0.00

In 1977 the crop yields of the field plots continued to respond favorably to soil additions.

A positive correlation was also determined to exist between the thickness of fertile soil and:

(1) an increase in essential nutrients in the plant growth medium
(2) a reduction in alkalinity
(3) an increase in sorption and in water capacity of the treated medium
(4) a decrease in radioactivity of the treated medium
(5) an increase in weight by volume, the result of greater compaction on the "soil" substrate, resulting in a decrease in vulnerability to water and wind erosion
(6) an increase in biological activity of the plant growth medium through creation of conditions favorable to growth of algae and bacteria.

These correlations were documented in section 8. Some increases in macro and microelements in the growth medium resulted from the addition of low moor and high moor peats, bentonite, and tertiary sand. Additions of farm manure did not bring expected effects in Halemba, but did produce high yield on some combinations of plants at Konin. Often accompanying these treatments was an increase in available macroelements, good development of soil microflora, increases in organic matter in tilled layer, and increases in sorption and in water capacity of the treated medium. In the greenhouse experiments, no clear correlations were found to exist between treatment with green manure and improvement in physico - chemical and biological characteristics of treated medium. In field experiments treatment with a green "manure" of maize produced crops in the second year from treatment plots in which grasses and forbs had not grown the first year, the second year yields of these plots were equivalent to those for plots treated with soil. The effects of fertilization with green manure are expressed in increased organic matter and macroelement content in the treated materials, in improvement of soil water-air characteristics, and in more intense biochemical processes. The favourable influence of green manure, and of farm manure, existed only in the second year of cultivation of grass and forbs.

The neutralization treatments in reference to forest reclamation were not sufficient, which fact indicate the high losses of planted cuttings, small annual increments and the incidence of diseases. The most effective method of reclamation of soil medium it seems to be the exchange of ash from the pits dug for the planting of cuttings for fertile soil. Such method was used in Konin in variant no. 5. On the basis of the 2-yearly experiment, one may say, that the losses of cuttings were decidedly lower here by some 5-45 % than on remaining variants of the experiment. And the annual increases in height were by 100-150 % greater here than on remaining variants.

Less effective was the back - filling of pits with mixture of ash with fertile soil in ratio of 3:10 + mineral fertilizers (NP). The losses were here much higher than on combination no. 5, and the increases in height much smaller. The remaining combinations with dressing pits with high moor peat, with bentonite, sand and mineral fertilizers were disappointing to such an extent, that losses of cuttings in the three years time approached 71 % in Konin (locust tree in combination no.3 with dressing pits with a mixture of ash and tertiary sand) and up to 92 % losses at Halemba (birch tree in combination no. 3, on dressing the pits with high moor peat + NP).

The tests of soil sampled from the 5-10 cm layer closest to the cuttings have shown, that changes in reaction and in chemical properties are here noticeable in relation only to combination no. 5 in Konin (back filling of pits with fertile soil supplemented with the NP fertilization), and to a lesser extent in combination no. 1, on both disposal stacks (pits backfilled with mixture of ash with fertile soil + NP). One may therefore conclude, that the effectiveness of the employed treatments in the forest reclamation is smaller than in agricultural reclamation.

The use of mineral fertilization in subsequent years for the tree and shrub cultivation - supplemented with digging of soil to depths of 5 to 10 cm is in effect contributing to intensive growth of weeds (also of grasses), choking the forest cultures. There is the belief, that the growth of weeds is contributing to intensification of the soil producing processes on disposal stacks, but the confirmation of this in laboratory tests may be only after a longer, at least few years, time period.

CULTIVATION OF HERBACEOUS PLANTS

To simplify the interpretation of the greenhouse experiments only white mustard was used (Synapis alba L.) since it is characterized with an easily noted response to changes in the growth environment. These tests facilitated specification of more promising variants of fertilization and neutralization for use under field conditions. These experiments indicated that high vegetation yields were obtained on treatments of ash with soil, on ash treated with low and high moor peats in various doses (more advantageous were high doses on the order of 100 t/ha peak), on mineral soil, and on green manure made of cereal grains and forbs (but only for Halemba). As the combinations with exclusive mineral fertilization were very promising, (particularly on ashes from Konin), therefore second greenhouse experiment was set up (fig. 32) in which determined was the correlation of crop level with the types of supplied macrocomponents. In ash from Konin a positive reaction to a composite NPK Mg fertilization was ascertained together

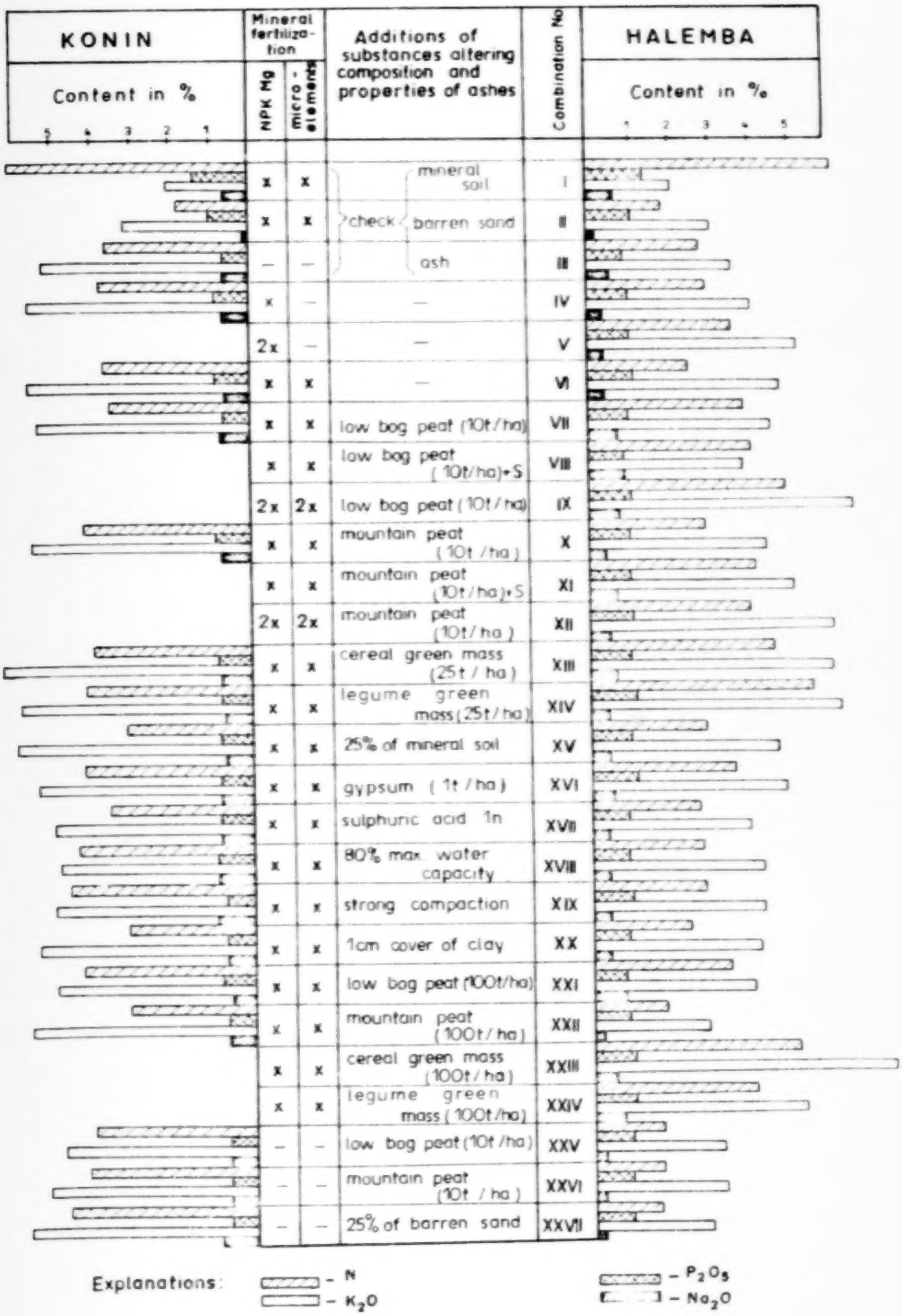

Fig. no. 34. Content of some constituents in white mustard, obtained from I greenhouse experiment.

with a required phosphorus and magnesium to be supple mented, and in ash from Halemba a strong reaction to complex mineral fertilization used in large doses was observed.

The field experiments, carried out over three years, confirmed in principle the greenhouse observations. Further, additional treatment variants were tried to refine the conclusions of the greenhouse experiments.

Under the field experiment conditions there existed the possibility of investigating the growth and development of a greater number of plants than was possible in the greenhouse experiments. On the basis of current research performed on other fly ash and considering the habitat and microclimatic conditions and plant requirements, five plant mixtures were used for the field tests. Initially promising was crown vetch - Coronilla varia - which under American conditions is reported to produce green mass but which is not particularly liked by agronomists. However, when sown with sainfoin - Onobrychis viciaefolia - on the rich calcium ash in Konin, it did not succeed. Only few seeds germinated. Sainfoin in its first seeding had also shown insufficient germination, and required reseeding at a high rate. Measureable yield of these species were not realized until the third year of the experiments and the yields were lower than for all plots with grasses and forbs.

Similarly, white melilot (sweet clover) did not give the desired results. The germination of white melilot both in Konin and in Halemba was not satisfactory. The treatment plots were overgrown with weeds.

The best growth results were achieved with mixtures of grasses and a mix of alfalfa and orchard grass.

As a criterion of success, the protein value of the crops was measured. These results are presented in figure 37.

From the comparisons of production of protein appears, that in Halemba the best results were achieved in cultivation of:

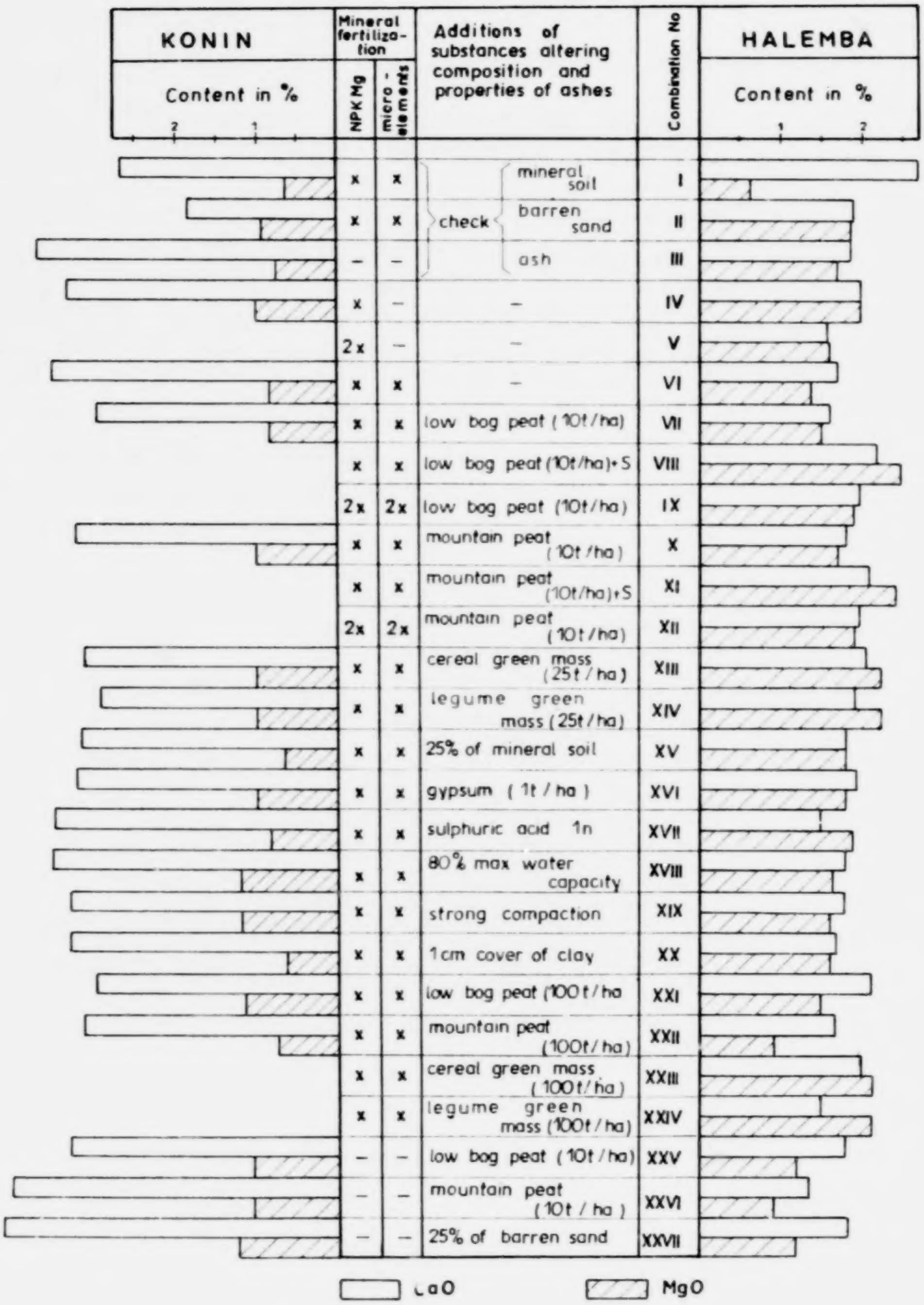

Fig. no. 35. CaO and MgO content in white mustard, from I greenhouse experiment.

- mixture no. 1 (lucerne and melilot), on ashes treated with low moor peat and fertilized with NPK - 1483 kg/ha of protein
- mixture no. 2 (grasses with legumes), on ashes covered with 20 cm layer of fertile soil and fertilized with NPK - 1410 kg/ha of protein
- mixture no. 4 (white melilot), on ashes covered with a 20 cm layer of fertile soil and fertilized with NPK - 1265 kg/ha of protein
- mixture no. 3 (lucerne and orchard grass) on ashes covered with 20 cm layer of fertile soil and fertilized with NPK - 842 kg/ha of protein.

Good results were also obtained on plots treated with low moor (E combination) and high moor peats. Mineral fertilization without enrichment of ash with humus gave small results, barely some 5-75 % higher than on not fertilized controls, from which there was obtained 375 - 603 kg/ha of protein.

On experimental plots in Konin the definitely highest amounts of protein were acquired from A combination in which the ash was covered with 20 cm layer of fertile soil and fertilized with NPK:

- the mixture no. 3 (lucerne and orchard grass) - 1515 kg/ha of protein
- the mixture no. 2 (grasses with legumes) - 1498 kg/ha of protein
- the mixture no. 4 (white melilot) - 1064 kg/ha of protein.

Relatively good results were achieved also from combination, where ashes were covered with thinner (10 cm) layer of fertile soil and with NPK. Satisfactory results were achieved on, plots fertilized with farm manure (mixture no. 3 - 1042 kg/ha of protein), with green manure (mixture no. 3 - 1071 kg/ha of protein), with low moor peat (mixture no. 3 - 1050 kg of protein), and with high moor peat (1086 kg of protein). Direct mineral fertilization gave unsatisfactory results (397 - 866 kg of protein), but much better than on ash of the control plots (77 - 676 kg of protein). Decidedly poor results gave cultivation of sainfoin (mixture no. 1).

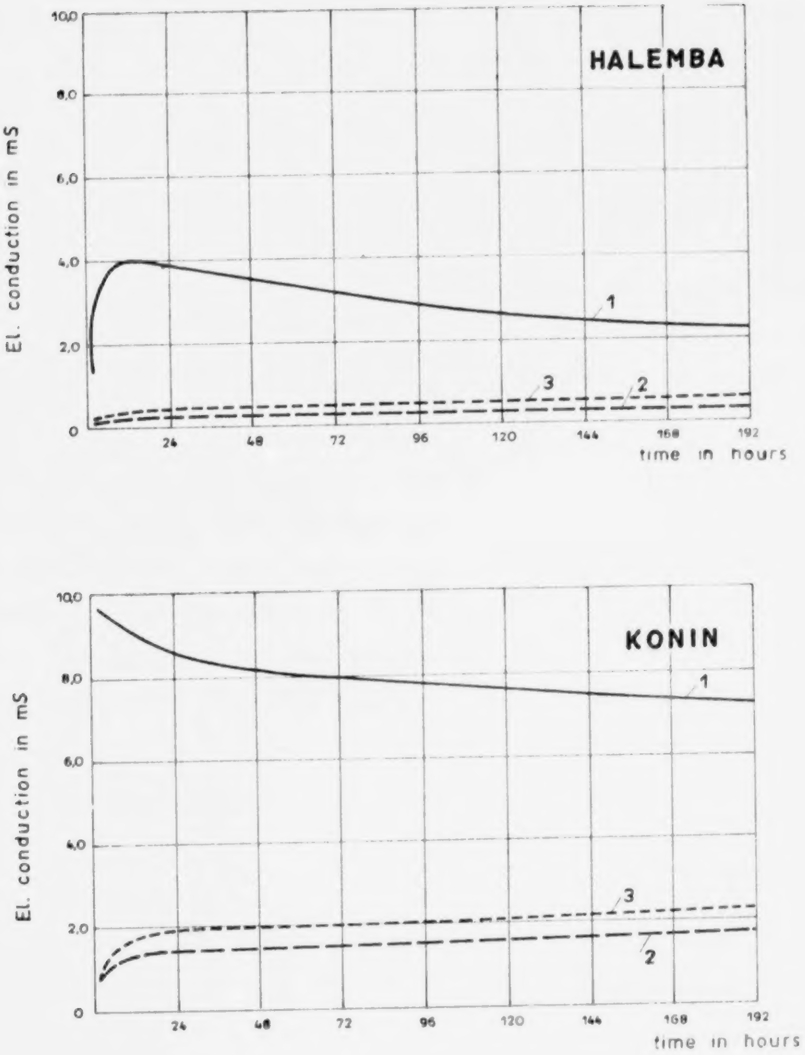

Fig. no. 36. Specific conduction of ashes of bituminous coal (Halemba) and of lignite (Konin)

1 - fresh ash from electrofilters

2 - fresh ash from sedimentation basin

3 - ash from experimental control plot (0) after a 3-years' cultivation of plants.

It appears from the presented comparisons, that both in Halemba and in Konin the best effects were acquired in cultivation of mixture no. 2 (grasses with legumes in proportions as provided in chapter 4) and the mixture no. 3 (lucerne and orchard grass).

In reference to the latter mixture it was found, that orchard grass is displaying here a very high aggressiveness. The proportion by weight of its seeds in the mixture amounted to 14 %, while the phytosociological survey made in the third year of cultivation had shown, that orchard grass was occupying 21 - 90 % of the plots´ surface in Halemba and 4 - 84 % in Konin. It seems that its aggresiveness was backed by profuse nitrogenous fertilization, with which the legumes cultivated in normal soil are not too happy.

Figure 33 presents the relationship between water consumption and of the yield of green mass for greenhouse experiments. A straight line relationship appears to exist, and therefore, the slope of the line represents the change in yields as a function of water consumption. Steeper slopes indicate higher benefits of water availability. For the greenhouse experiments, the following treatments appeared to produce higher responses to water consumption:

(1) on ash from Halemba: no treatment, treatment with a high rate of green manure and full fertilization, treatment with mountain peat, and treatment with river sand;

(2) on ash from Konin: treatment with large amount of green manure and full fertilization treatment with a double rate of fertilization with macro elements, treatment with small amounts of green manure and treatment with mountain peat and fertilized.

The results show that a high yield under field conditions was obtained with the application of green manure in Konin. The plants growing in this treatment used the precipitation water with high efficiency.

In making the comparison of chemical composition of plants coming from neutralized ashes in the first greenhouse experiment the attention draws mainly (fig. 34 and 35):

a) the low content of nitrogen in relation to the control pot, which was white mustard cultivated on fertile soil,

b) the higher (2-3 times) content of K_2O, particularly in combinations fertilized with green mass of cereal plants, and low moor peats,

c) the generally low content of P_2O_5,

d) the higher by 45 % content of CaO in plants coming from Konin, and the generally lower CaO content in plants cultivated on ashes from Halemba,

e) the up to 2-3 times higher content of MgO in plants cultivated on ashes from Halemba, particularly in combinations fertilized with peats and green manure.

The above relations were not confirmed fully by the field experiment, and so:

a) the smallest amounts of nitrogen were found in composition of hay coming from the not fertilized control plots in Halemba, however the deviations from compositions of plants growing on natural soils were small; in Konin the highest N content had yields from plots covered with fertile soil,

b) no greater deviations in hay content were found in K_2O, P_2O_5, CaO and Mg in relation to experimental plot covered with 20 cm layer of fertile soil,

c) in hay coming from both ash disposal stacks was found insufficient amount of copper, but quite high was content of iron; similar relations are found in crops from peaty soils,

d) in crops of plants collected from plots covered with fertile soil and NPK the deficit of such components as B, CaO, K_2O was found only when the used fertile soil was deficient in the same elements, and this applied even when the ash subsoil possessed these components in excess, pointing to small degree of utilization of available in deeper layers of produced soil excess elements; the surplus of Zn in brought in fertile soil, contributed to an excess reserve of this element in the hay,

e) in some combinations - particularly with lack of organic fertilization were found comparatively high amounts of molybdenum (to 6.15 ppm in Halemba, and to 8.5 ppm in Konin) which could affect the usefulness of hay to animals.

CULTIVATION OF TREES AND BUSHES

In the course of the 3-year period of the investigations of silvan reclamation of ash disposal stacks, a number of correlations between trees, shrubs, and ash treatments were observed. The most important of these are:

a) the correlation of numerical losses of specimens with the characteristics of ashes and treatments there of, and

b) the correlation of growth of particular species of trees and bushes with characteristics of ashes.

Add. a) The number of losses of selected species was very high, and is not normally encountered in reforestation. The dead species were replaced up to two times (in 1975 and in 1976) but on some plots the number of surviving cuttings constitutes a small percent of planted cuttings. For example, 1853 cuttings were planted at Halemba in 1975 through 1977, but by the end of 1977 only 853 (45.0 percent) of the cuttings survived. At Konin, only 40.2 percent of the cuttings survived.

This would imply a more suitable environment at Halemba for forest type reclamation.

Add. b) The total growth of trees and shrubs in terms of height increases was, on the average, 0.69 m at Halemba and 0.36 m at Konin. This again points to better conditions for forest reclamation at Halemba. The more favorable species may be determined by the survival rate as well as by the growth rate. In terms of survival, the best results were obtained from the following species (organized from highest to lowest survival):

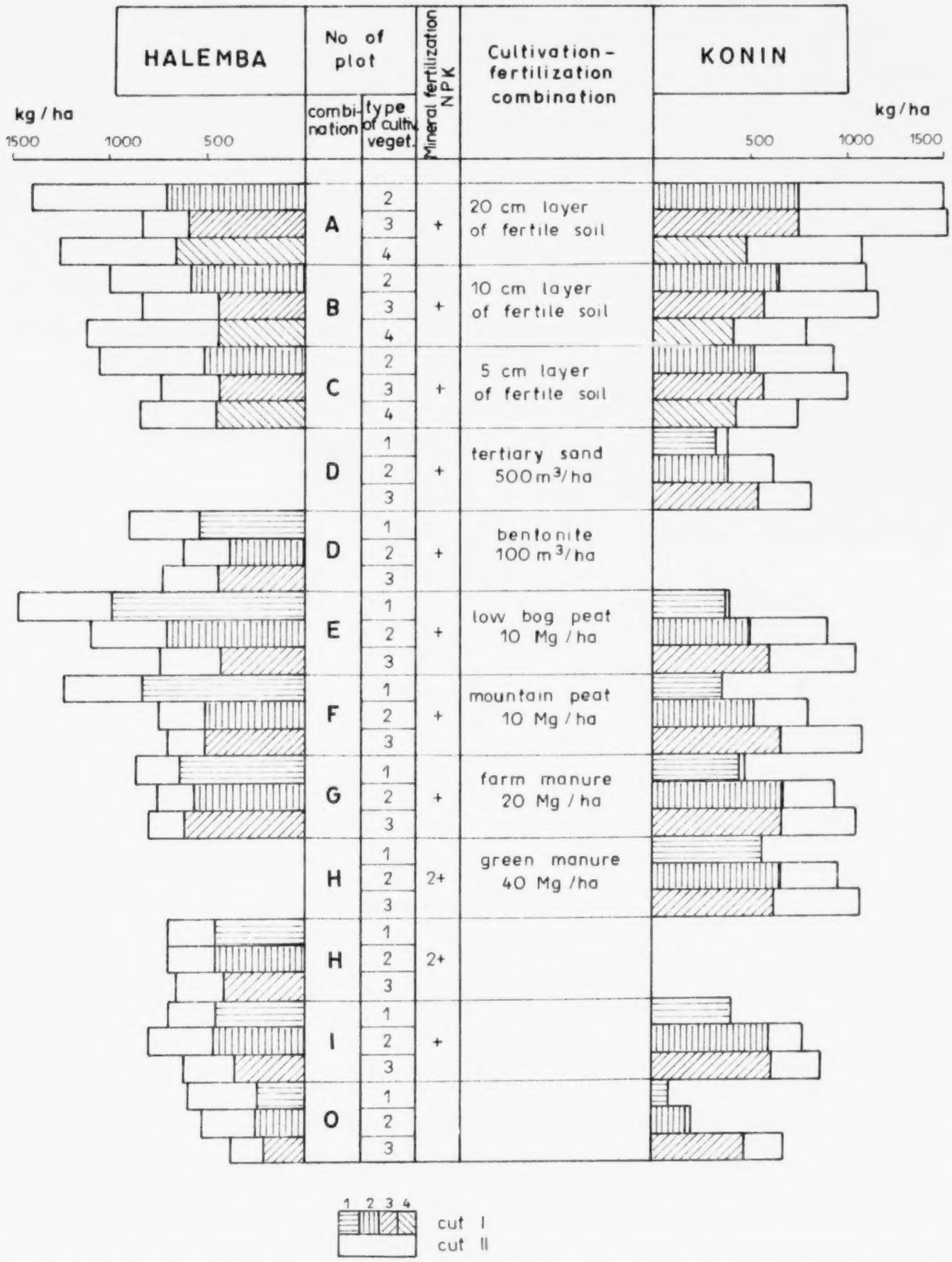

Fig. no. 37. Fodder value of cultures from field experiments in Halemba and Konin.

Halemba:		Konin:	
1) locust tree	- 1.0 %	1) poplar I	- 43.3 %
2) poplar I	- 5.5 %	2) grey alder	- 47.0 %
3) poplar II	- 11.1 %	3) poplar II	- 47.8 %
4) pea shrub	- 24.2 %	4) willow	- 49.4 %
5) basket willow	- 27.2 %	5) pea shrub	- 52.0 %
6) black alder	- 42.9 %	6) larch	- 53.4 %
7) grey alder	- 44.4 %	7) sea buckthorn	- 55.3 %
8) larch	- 72.5 %	8) locust tree	- 58.3 %
9) birch	- 88.5 %	9) black alder	- 58.4 %
		10) birch	- 62.3 %

Similar classification in terms of growth height gives the following results:

Halemba:		Konin:	
1) locust tree	- 2.12 m	1) locust tree	- 0.63 m
2) pea shrub	- 1.03 m	2) willow	- 0.49 m
3) poplar II	- 0.70 m	3) grey alder	- 0.43 m
4) poplar I	- 0.62 m	4) birch	- 0.36 m
5) black alder	- 0.47 m	5) black alder	- 0.35 m
6) grey alder	- 0.47 m	6) poplar II	- 0.31 m
7) willow	- 0.33 m	7) poplar I	- 0.29 m
8) birch	- 0.29 m	8) sea buckthorn	- 0.28 m
9) larch	- 0.28 m	9) pea shrub	- 0.13 m
		10) larch	- 0.11 m

From the above comparisons, it appears that the best specie at Halemba was locust (Robinia pseudoacacia). and sea buckthorn (Hippophae rhamnoides), and pea shrub (Largana arborescens), and at Konin locust grey alder (Alnus incana) and sea buckthorn.

The treatment plots can be evaluated also based on the survival of plants and on the growth rates of the surviving species. In terms of survival the treatments are ranked as follows (highest to lowest):

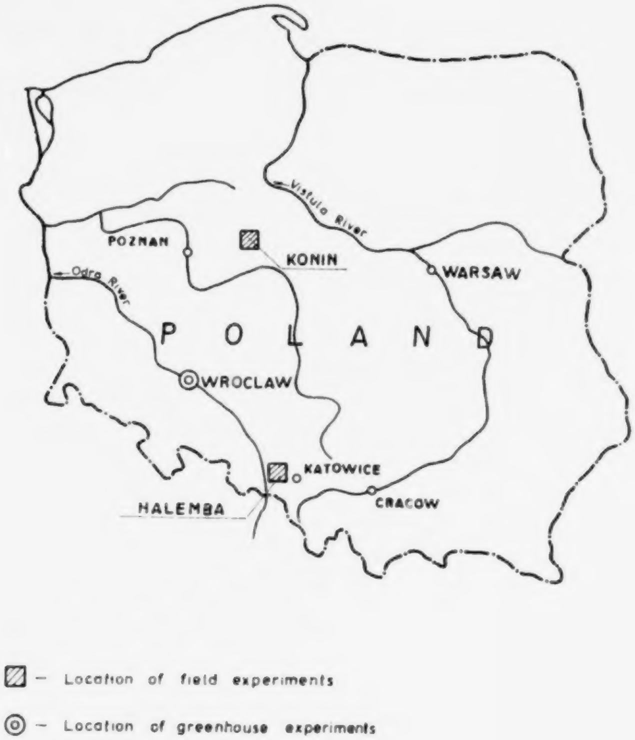
Vistula River
POZNAN
KONIN
WARSAW
Odra River
P O L A N D
WROCLAW
KATOWICE
CRACOW
HALEMBA
▨ – Location of field experiments
◎ – Location of greenhouse experiments

Fig. no. 38. Location of greenhouse and field experiments.

Halemba:

1) Combination no. 2 - dressing pits with a mixture of ash and bentonite + mineral fertilizers - 39.5 % losses;

2) Combination no. 1 - dressing pits with a mixture of ash with fertile soil in 3:1 proportion + mineral fertilizers - 40.1 % losses;

3) Combination no. 3 - dressing pits with a mixture of ash and high moor peat (8 kg/m^3 of ash) + mineral fertilizers - 41.3 % loses;

4) Combination no. 4 - backfilling pits with ash and mineral fertilizers - 43.8 % losses.

Konin:

1) Combination no. 5 - dressing pits with fertile soil + mineral fertilizers - 20.5 % losses;

2) Combination no. 3 - dressing pits with a mixture of ash and high moor peat (8 kg/m^3) + mineral fertilizers - 59.7 % losses;

3) Combination no. 4 - backfilling pits with ash + mineral fertilizers - 60.3 % losses;

4) Combination no. 2 - backfilling pits with ash and tertiary sand + mineral fertilizers - 61.6 % losses;

5) Combination no. 1 - backfilling pits with mixture of ash with fertile soil, 3:1 proportion, + mineral fertilizers - 65.8 % losses.

In terms of growth, the treatments are ranked as follows:

Halemba:

1) Combination no. 1 - average increase of 0.74 m
2) Combination no. 3 - average increase of 0.73 m
3) Combination no. 4 - average increase of 0.67 m
4) Combination no. 2 - average increase of 0.65 m

Konin:

1) Combination no. 5 - average increase of 0.60 m

2) Combination no. 2 - average increase of 0.40 m
3) Combination no. 4 - average increase of 0.39 m
4) Combination no. 3 - average increase of 0.35 m
5) Combination no. 1 - average increase of 0.31 m

The treatments with soil appear to give the best results, with the results improving in proportion to the amount of soil used.
The chemical composition of leaves was analysed only for the locust tree. The other combinations had only scanty leafage, and there was not enough material to perform the necessary analyses, and what more, the plucking of all leaves would endanger the results of observations of these trees and bushes in the following years. The analyses of chemical compositions - in this the contents of such microelements as the B, Cu, Mn, Mo, Zn, Co - were not indicating any substantial differences in comparison to trees growing in natural soils.

The limited time available to examine soil changes at Konin has not yet permitted generalizations as to the successes and failures of trees and shrubs there.

REFERENCES

1. Adams L.M., Capp J.P., Gillmore D.W.: Coal Mine Spoil and Refuse Bank Reclamation with Powerplant Fly Ash. Compost Science No. 6/1972, p. 20-29 (Eng.)

2. Adams L.M. Capp J.P., Eisenstrout E.: Reclamation of Acid Coal-Mine Spoil with Fly Ash. Report of Investigations 7504. Ed. United States Department of the Interior, Bureau of Mines, 1971, p. 29 (Eng.)

3. Barber E.G.: Win back the acres. The treatment and cultivation of PFA sulfaces. London. Central Electrificity Generating Board. 1972 (Eng.)

4. Borkowski J., Krężel R., Nowak W., Wysocki W.: Aktywizacja popiołów z węgla brunatnego dla produkcji roślinnej. Górnictwo Odkrywkowe 1976, No. 4, p. 416-421 (Pol.)

5. Buckman H.C., Brady N.C.: Gleba i jej właściwości (tłum. z ang.) The Nature and Properties of Soils - Ed. VII. The Macmillian Company, 1960, Edition PWRiL, Warszawa 1971, pp. 530. (Pol.)

6. Drożdż H.: Zabezpieczenie składowisk popiołu przed pyleniem i ich rekultywacja. Biuletyn Techniczny - Elektrownie, Elektrociepłownie. Edition: Energoprojekt, Warszawa, No. 1/1970, p. 112-119. (Pol.)

7. Góra E.: Na przykładzie elektrowni Pietrafitta - co robić z popiołem. Aura no. 5/75, p. 17 (Pol.)

8. Greszta J., Morawski S., Godzik S.: Die Beforstung von Halden der Energetik, Iw: III Internationales Symposium über Rekultivierungen der durch den Bergbau beschädigten Böden. Referaten - Sammlung. Praha 1967, p. 241-247. (Ger.)

9. Grochowski H., Pruchnicki J.: Wykorzystanie wody do zabezpieczania hałd popiołów przed pyleniem. Gospodarka wodna 1973. No. 6, p. 232-235 (Pol.)

10. Hodgson D.R. Townsend W.N.: The amelioration and Revegetation of Pulverized Fuel Ash. Hutnik (D) 1440, II, p. 247-271 (Eng.)

11. Hryncewicz Z., Balicka N., Giedrojć B., Małysowa E.: Badania and utrwaleniem i zagospodarowaniem hałdy popiołowej w Elektrowni Halemba. In: XIX Ogólnopolski Zjazd Naukowy Polskiego Towarzystwa Gleboznawczego - Komunikaty. Ed.: PTG Puławy 1972, p. 452-460 (Pol.)

12. Hycnar J.: Przeciwdziałanie zanieczyszczeniu atmosfery przez składowiska odpadów paleniskowych. Ochrona Powietrza. No. 2/1972, p. 15-18 (Pol.)

13. Kuziemska J., Nowak J.: Wstępne badania nad biologicznym zapobieganiem pyleniu terenów zwałowisk przemysłowych. Górnictwo Odkrywkowe No. 8/1974, p. 238-240 (Pol.)

14. Leroy J.C., Keller H.: How to reclaim mined areas, tailing. In.: Mining Congres Journal. 1971 (Eng.)

15. Maciak F., Liwski S., Pronczuk J.: Rekultywacja rolnicza składowisk odpadów paleniskowych (popiołów) z węgla brunatnego i kamiennego. Soil Science Annual 1976, v. XXVII, inst. z. 4, p. 149-209 (Pol.)

16. Maly Vl.: Die landwirtschaftliche Rekultivierung von Schlacken - Flugaschenabladeplätzen der Kraftwerke. In: III Internationales

Symposium über Rekultivierungen der durch den Bergbau beschädigten Böden. Referaten - Sammlung. Praha 1967, p. 522-529 (Ger.)

17. Maly Vl.: K otázce zemedelské rekultivace slozisť elektrareń. In: Vedecke prace Výzkumnoho Ustavu Melioraci, Praha, No. 10/1969, p. 91-108 (Czech.)

18. Maly Vl.: Volba vchodnych travin pro ozeleneni zlozist elektráren. Ochranarsky pruzkom. No. 10/1973. (Priloha casopisu Ochrana prirody), p. 37-40 (Czech.)

19. Martens D.C.: Agricultural Uses of Fly Ash. In: Reports of the Polish - U.S. Symposium "Environmental Protection of Openpit Coal Mines" Denver, Co. 1975. Ed. The University of Denver Research Institute, Denver, Co 1975, p. 109-116 (Eng.)

20. Patterson J.C., Capp J.P.: Turf Soil Modification with Sintered Fly Ash. Report of Investigations 7381. Ed. United States Department of the Interior, Bureau of Mines 1970. Duplicated typescript, p. 12 (Eng.)

21. Pikałowa G.M.: Wykorzystanie roślinności wieloletniej dla celów rekultywacyjnych. In: Materiały Międzynarodowego Sympozjum Rekultywacji Terenów Poprzemysłowych. Katowice 1965, p. 203-206. (Pol.)

22. Składowanie i zagospodarcwanie odpadów energetycznych i hutniczych. Częstochowa 1973 - Materiały, Edition Geological. Warszawa 1973 pp. 454. (Pol.)

23. Szczygieł P., Godzik St., Kotulski B.: Próba zazielenienia zwałowisk popiołu z elektrociepłowni. Gospodarka Paliwami i Energią No. 7/1963, Wyd. Czasopism Technicznych NOT, Warszawa (Pol.)

24. Štine E.A.: Razvitie vodoroslej na promyšlennych odvalach. In: III Internationales Symposium über Rekultivierungen der durch

den Bergbau beschädigten Böden. Referaten - Sammlung. Praha 1967, p. 538-544.(Russ in Ger. Ed.)

25. Tarczewskij W.W.: Utrwalanie i konserwacja powierzchni drobnopyłowych zwałowisk przemysłowych. In.: Materiały Międzynarodowego Sympozjum Rekultywacji Terenów Poprzemysłowych. Katowice 1965, p. 51-54 (Pol.)

26. Tarčevskij V.V., Pikalova G.M., Levit S.J., Šilova M.V.: Forschungsarbeiten zur Rekultivierung von Aschenkippen. In: IV Symposium über die Wiedernutzbarmachung der durch die Industrie devastierten Territorien. Leipzig 1970, p. 314-317.(Ger.)

27. Tonet N.R.: Hydraulic Disposal to Mines. ASME-IEEE Joint Power Generation Conference ASCE Participating Society Pittsburgh, Pa 1970. Duplicated typescript, p. 13 (Eng.)

28. Vaniček Vl.: Entwicklung und Wuchs der Wegetation auf Abladeplätzen für Abfallstoffe von Wärmekraftwerken. In: III Internationales Symposium über Rekultivierungen der durch den Bergbau beschädigten Böden. Referaten - Sammlung. Praha 1967, p. 552-556. (Ger.)

29. Wagner E.: Die Wiedernutzbarmachung von Aschehalden und Absetzanlagen der Wärmekraftwerken. Neue Bergbautechnik No. 1/1974, p. 30-34 (Ger.)

30. Wysocki W.: Centralne Zwałowisko Kotlarnia i jego rekultywacja. In: Składowanie, zagospodarowanie odpadów energetycznych i hutniczych. Geological Edition, Warszawa 1973, p. 251-254. (Pol.)

31. Wysocki W.: Właściwości fizykochemiczne i biologiczne popiołów z elektrowni Rybnickiego Okręgu Węglowego. In.: Składowanie i zagospodarowanie odpadów energetycznych i hutniczych. Geological Edition, Warszawa 1973, p. 83-92 (Pol.)

32. Wysocki W.: Wykorzystanie popiołów elektrowni Turów do neutralizacji zwałowisk nadkładowych kopalni Turów. In: Składowanie i zagospodarowanie odpadów energetycznych i hutniczych. Geological Edition, Warszawa 1973, p. 447-450 (Pol.)

33. Wysocki W.: Reclamation of Coal-Fired Power Plant Ash Piles. In.: Reports of the Polish - U.S. Symposium "Environmental Protection of Openpit Coal Mines", Denver, Co 1975. Ed. The Uniwersity of Denver Research Institute, Denver, Co. 1975, p. 97-108. (Eng.)

34. Żak M.: Wpływ powłok asfaltowych przeciwdziałających wtórnemu pyleniu składowisk popiołów lotnych na wegetację roślin. In: Komunikaty XIX Ogólnopolskiego Zjazdu Naukowego Polskiego Towarzystwa Gleboznawczego. Ed. PTG Puławy. 1972, p. 488-496. (Pol.)

35. Żurawski M.: Wstępne badania nad możliwością zagospodarowania hałd popiołowych elektrowni Łaziska Górne. In.: Komunikaty XIX Ogólnopolskiego Zjazdu Naukowego Polskiego Towarzystwa Gleboznawczego. Edition PTG. Puławy 1972, p. 461-467. (Pol.)

36. Allen O.N.: Experiments in soil bacteriology. Wyd. III. Burgess Publ. Co. Minneapolis, Minnesota 1957.

37. Ashby S.: Some observationson the assimilation of atmospheric nitrogen by the free living soil organisms Azotobacter chroococcum. Journal Agric. Sci 1907 nr 2

38. Bristol B.M.: On the alga-flora of some desiccated English soil an important factor in soil biology. Ann. Bot. 1920, nr 34, p. 35-79

39. Conn H.J.: The use of various culture media in characterizing actinomyces ". N.Y. Agr. Exp. St. Tech. Bul. 1921 nr 83

40. Hoffmann E.: Ensymreaktion und ihre Bedeutung für die Bestimmung der Bodenfruchtbarkeit. 2.f. Planzenernährung, Düngung, Bodenkunde 1952 nr 56 B z 1-3 p. 68

41 Johnson L.F.: Effect of antibiotics on the members of bacteria and fungi isolated from soil by the dilution - plate method. Phytopathology 1957 nr 47 p. 630-631

42 Johnson L.F., Curl E.A.: Metods for research of the ecology of soil - borne Plant Pathogens. Wyd. Burgess Publishing Company. Minneapolis, Minnesota 1972

43 Kowaliński St., Borkowski J., Giedrojć Br., Pul W., Szerszeń L.: Ćwiczenia z gleboznawstwa i podstaw mineralogii z petrografią. Wyd. IV. Wyższa Szkoła Rolnicza Wrocław 1969, pp. 299.

44 Martin J.P.: Use of acid, rose bengal and streptomycin in the plate method for estimating soil fungi. Soil Sci 1950 nr 69, p. 215-232

45 Rodina A.: Mikrobiologiczne metody badania wód. Wyd. PWRiL Warszawa 1968.

46 Polska Norma PN-69/H-04154 - Analiza chemiczna materiałów ogniotrwałych glinokrzemianowych.

Edition in language:

(Czech.) - Czech
(Eng.) - English
(Ger.) - German
(Pol.) - Polish
(Russ.) - Russian.

GLOSSARY

acrylate emulsion: Is a water dispersion of acrylate-etherine copolymer (semi-product in emulsion paint manufacture) Solubility in water very good. Producent Dębicka Factory of Paints and Varnishes in Dębica, Poland.

agricultural reclamation: Technical, agrotechnical and biological treatments connected with restoration to the transformed in the effect of industrial activity soils of their production capacity or utility value in agriculture.

bentonite: Waste matter derived from the cycle system of mont morillonite - clayey sediments with a variable mineral composition, characterized with the presence of minerals of the mica group, indicating also different stages of degradation in the direction of the mont morillonite typified with a sorptive capacity of 50--70 mval/100 g.

bulk density: Weight of soil after drying in temp 105°C determined in Kopecky cylinders, of 250 cm^3 capacity [43].

capillary potential: (pF curve), defines forces bonding water in the soil. It is expressed as the height of water column and amounts from 0 (full saturation of soil with water), to 6.000.000 = 6,000 atmospheres (soil dried in temp. 105°C). To avoid the use of high numbers, one introduces the sign $pF = \log_{10} h$ /cm/ of water column, corresponding to the force bonding water in soil. The field water capacity corresponds to pF 2.54 (0.34 atm), maximum hygroscopicity - pF 2.2 (0.15 atm) to pF 4.2 (15 atm.).

capillary water capacity: Ability to retain water by soil in capillary voids determined in samples of undisturbed structure in Kopecky cylinders [43]

clutan: See waste sulphite lye.

Hüls - Bodenfestiger Hüls 801 - preparation for protective consolidation of terrain surfaces without fertile soil shield; produced in West Germany in Chemical Works Hüls. Trade name and chemical composition reserved.

curasol: Preparation for protective consolidation of soil surface, product of West Germany. Trade name and composition reserved.

curie: Unit of specific activity of radioactive source, defined as the quantity of radioactive substance in which the disintegrations per second amount to 3.7×10^{10}.

Abbreviation "Ci"; $1 pCi = 10^{-12}$ Ci.

fertile soil: Soil from humus horizon of agricultural lands with at least an average fertility.

forest reclamation (silvan reclamation): Technical, agrotechnical and biological treatments connected with the restoration to the transformed soils of their production or utility value in forestry.

field water capacity: Ability of soil to retain water by capillary forces above the reach of the capillary rise in pores smaller than 8.5 jum, corresponding to 0.345 atm. pressure (33 800 Pa), and to the pF = 2.5 value. Water available for plants is taken to be water quantity contained between the field water capacity and the point of withering (pF = 4.2 corresponding to pressure of 15 atm. = 1471 kPa) [43].

general porosity: Total sum of all free voids occurring in soil, determined by indirect methods utilizing designations of weight density (S), bulk density (So) of soil according to formula

$$Po = \frac{S - So}{S} \cdot 100$$

or by direct methods using Nitsch air pycnometer [43]

latex LB 6041: Is a suspension containing up to 50 percent butadiene - styrene rubber and essential stabilizing agents. Its dissolubility in water is very good, and working time is 3 months. Product of the Oświęcim Chemical Works, Oświęcim, Poland.

low moor peat: Peat formed in river valleys of trees, water plants, and grasses deposited in conditions of strong mineralization.

micelle (radical): Strongly charged anion of colloidal particles (nucleus), surrounded by adsorbed cations [5].

mountain moor peat : Mountain peat formed of sphagnum mosses in an acid eutrophic medium.

protection against secondary dusting: Consolidation of surface of the ash disposal stack in a manner preventing the emission of dusts to atmosphere.

salinity: excessive concentration of easily soluble salts in water (chlorides or sulphates of sodium or of magnesium, carbonates and bicarbonates of sodium) when their total content computed in conversion to NaCl is greater than 0.3 % (gravimetrically). For practical purposes the degree of salinity is measured in g of NaCl per 1 dm^3 of soil.

secondary dusting: emission of dusts from disposal stack of ash to the atmosphere.

simens: unit of electric conduction defined as the reverse of a unit of electric resistance: $1S = \frac{1}{ohm}$; $1\ mS = 10^{-3} S$.

waste sulphite lye: Is a waste product in paper production and containing lignosulphonate complex, saccharoses, organic and mineral acids and their salts. The waste product is in the form of liquid with 50 percent concentration, or in dry form as chips, and is named Clutan. Well soluble in water.

weight density: Ratio of dry mass devoid of soil air to the mass of same volume of water. Determined by pycnometer, by calibrated flask, or by spirit method [43] .